SPECIFICATION

METHOD AND DEVICE FOR EXPOSURE CONTROL,
METHOD AND DEVICE FOR EXPOSURE, AND
METHOD OF MANUFACTURE OF DEVICE

5   TECHNICAL FIELD

The present invention relates to a projection exposure apparatus for use in a lithography process in a manufacture line for manufacturing semiconductor devices, liquid crystal display devices, and so on. Further, the present invention

10 relates to a projection exposure method which uses such a projection exposure apparatus in the lithography process. Moreover, the present invention relates to a method for the manufacture of a device such as, for example, semiconductor elements, image pickup elements (CCDs, etc.), liquid crystal

15 display elements, thin film magnetic heads, and so on, by transcribing a device pattern on a mask onto a photosensitive substrate by means of the projection exposure apparatus.

BACKGROUND TECHNOLOGY

20 There are known plural types of projection exposure apparatuses for transcribing a pattern of a reticle as a mask onto each shot region on a wafer with a photoresist coated thereon, upon manufacturing, for example, semiconductor elements, and so on. The projection exposure

25 apparatuses of plural types may include, for example, a reduced projection exposure apparatus (a stepper) of a step-and-repeat type (of an overall exposure type) and a projection exposure apparatus of a so-called step-and-scan

type which is so adapted as to transcribe a reduced image of

the pattern on the reticle sequentially on each of shot

regions on the wafer by scanning the reticle and the wafer

in synchronization with a projection optical system in such

5   a state that a portion of the pattern on the reticle onto

the wafer through the projection optical system in a reduced

manner.

In exposing the wafer by means of such a projection

exposure apparatus, it is necessary to irradiate the wafer

10   with an exposure light at a predetermined exposure light

amount sufficient to expose a photoresist to light and sense

it on the basis of characteristics such as, for example,

sensitivity of the photoresist coated on the wafer. In the

case where the light amount of the exposure light to be

15   irradiated on a wafer during exposure is known, a

predetermined total exposure light amount can be provided in

an exposure region on the wafer by controlling the exposure

time, on the one hand, in the case where the projection

exposure apparatus is of a step-and-repeat type, and by

20   controlling the scanning velocity or the like, on the other

hand, in the case where the projection exposure apparatus is

of a step-and-scan type.

For conventional projection exposure apparatuses, a

total exposure light amount on the wafer surface is obtained

25   by computation from an incident light amount incident to a

projection optical system and a transmittance or

transmissivity of the projection optical system, assuming

that a transmittance of the projection optical system does

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not fluctuate and is always stayed constant during the exposure.

The transmittance of the projection optical system is computed from an leaving light amount of the light leaving from the projection optical system and an incident light amount of the light incident to the projection optical system, by measuring the leaving light amount, prior to starting the exposure operation, by means of an irradiation amount monitor disposed in a region separate from a wafer on a wafer stage.

Recently, a degree of integration for semiconductor devices and so on has become higher and higher, so that it is required to shorten a wavelength of the exposure light for use in projection exposure, in order to compete with a degree of minuteness of a line width of a pattern to be exposed. Thus, projection exposure apparatuses have been launched, which use an illumination light of an ultraviolet wavelength region, such as, for example, a Krf excimer laser having an oscillating wavelength of 248 nm or an ArF excimer laser having an oscillating wavelength of 193 nm. It has now been found by us, however, that in the case where such projection exposure apparatuses use a projection optical system of a reflection-refraction type or of a refraction type, a transmittance of quartz which is used for an optical element of the projection optical system thereof and a transmittance of a coating formed on surfaces of quartz and a lens may fluctuate in such ultraviolet wavelength, upon irradiation with such a laser light.

Therefore, when such a light in an ultraviolet wavelength region (for example, KrF excimer laser having a wavelength of 248 nm or ArF excimer laser having a wavelength of 193 nm, etc.) is irradiated as an illumination

5   light, the irradiation of such an illumination light may cause the problem with fluctuation of a transmittance of an optical element or an coating material (for example, a thin film such as a reflection preventive film, etc.) for the optical element. Further, new problems may arise such that

10   a transmittance of the projection optical system may be caused to fluctuate due to foreign materials which may be generated from gases (e.g., air, etc.) present in a space interposed among plural optical elements, or from adhesive for use in fixing the optical elements to barrels of mirrors,

15   or from foreign materials (e.g., water, hydrocarbons or other substances for diffusing an illumination light, etc.) derived from an inner wall of the barrel, and which are attached on the optical element or enter in an illumination light path or are floating therein.

20   Therefore, even if the total actual exposure light amount to the wafer would be controlled by measuring only the incident light amount of the illumination light incident to the projection optical system during the exposure on the basis of the assumption that the transmittance of the

25   projection optical system would be stayed at a constant level as in conventional techniques, the problem may be caused such that an error in the total actual exposure light amount in the wafer surface is caused to occur by a portion

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corresponding to a fluctuation of the projection optical system during the exposure and an optical exposure light amount cannot be provided on a photoresist on the wafer.

Further, when the attached materials is detached from the surface of the optical system by irradiation of a light in an ultraviolet region, a transmittance of the optical system is allowed to rise by an actual exposure (i.e., by irradiating the mask with an exposure light by an illumination optical system and projecting a pattern on a mask onto a photosensitive substrate by the projection optical system).

A brief description will be made of the such phenomenon with reference to Fig. 31. Fig. 31 shows a graph showing a distribution of transmittances in states after passage of the exposure light through the optical element for a predetermined period of time. In the graph of Fig. 31 which the coordinates on an image plane (a wafer plane) in an original section are indicates by representing a transmittance (%) on the Y-axis and representing a light axis as an original point on the X-axis. Fig. 31(a) shows a transmittance distribution in a reference state; Fig. 31(b) shows a state in which a predetermined period of time (duration A) has elapsed since the stop of the exposure; Fig. 31(c) shows a state in which the exposure light has passed through the optical element after an elapse of another period of time (duration B) from the state as shown in Fig. 31(b); Fig. 31(d) shows a state in which the exposure light has further passed through the optical element after an

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elapse of a further additional period of time (duration C) from the state as shown in Fig. 31(c); and Fig. 31(e) shows a state in which the exposure light has further passed through the optical element after an elapse of a still further additional period of time (duration D) from the state as shown in Fig. 31(d).

As shown in Figs. 31(a) to 31(e), inclusive, the problems may also arise such that a distribution of transmittances of the optical system may fluctuate as well as transmittances of the optical system in the projection exposure apparatus may fluctuate.

The fluctuation of the transmittance and the distribution of the transmittances may cause the problems that a deviation of the exposure light amount to be provided on the photosensitive substrate from an appropriate value to a great extent and an irregularity of the exposure light amounts (an irregularity of illuminance) is caused to occur in an exposure region on the photosensitive substrate (a distribution of the exposure light amount (a distribution of illuminance) being deviated from a desired state) in the exposure region). If such an irregularity of the illuminance is caused to occur in the exposure region, the exposure light amounts cannot be distributed in the exposure region in an appropriate manner so that the problems may arise in that line widths may become irregular and devices may become poor in quality.

DISCLOSURE OF THE INVENTION

The present invention has the object to prevent a

fluctuation of an imaging characteristic of a projection optical system due to a variation in transmittance.

The present invention has another object to provide a method for controlling an exposure light amount and a device for controlling an exposure light amount as well as an exposure method and an exposure apparatus, each being so adapted as to control an accumulated exposure light amount of light to be irradiated on a wafer, without undergoing an influence from a variation in transmittance of the projection optical system.

The present invention has a further object to provide a manufacture method for manufacturing a circuit element (a device), which can form a pattern on a substrate in a favorably imaging state always at an optimal exposure light amount, even if the such fluctuation of the transmittance would be caused to occur during transferring the mask and the substrate in synchronism with each other.

The present invention has a still further object to provide a manufacture method for manufacturing a circuit element device, which can form an image of a pattern on a substrate in a favorably imaging state always at an optimal exposure light amount, even if the such fluctuation of the transmittance would be caused to occur.

The present invention has a still further object to provide a method for transcribing a device pattern formed on a mask onto a photosensitive substrate without undergoing an influence from an irregularity of illuminance over an entire area of an exposure region.

In order to achieve the objects as described above,
the present invention provides an exposure light amount
control method for controlling an exposure light amount on a
substrate upon projecting and exposing an image of the
5   pattern on the table onto the substrate through the
projection optical system by illuminating the pattern on the
reticle, which is characterized by the step of computing an
exposure light amount on the substrate on the basis of a
variation in an attenuation factor (a variation in
10   transmittance of an incident light amount incident to the
projection optical system) of a light amount of light
passing through the projection optical system. It is to be
noted herein that, in the transmittance of the projection
optical system as referred to in connection with the present
15   invention, a reflectance or reflectivity of a reflecting
member is also taken into account, in the case where the
projection optical system contains the reflecting member.
Moreover, the exposure light amount control method is
characterized by further containing the step of comparing
20   the exposure light amount with a predetermined exposure
light amount. In addition, an illumination light for
illuminating a reticle is characterized by having a
wavelength of 250 nm or less. The illumination light has a
wavelength of, preferably, 220 nm and, more preferably, 200
25   nm or less. The method further comprises the step of
measuring a variation in transmittance of the incident light
amount of the light incident to the projection optical
system and the step of saving the variation in transmittance

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thereof.

Further, the present invention provides the exposure light amount control method for controlling the exposure light amount on the substrate upon projecting and exposing a pattern on the reticle onto the substrate through the projection optical system by illuminating the reticle with a pulse light and scanning the reticle and the substrate in synchronism with each other, the exposure light amount control method being characterized further by the step of computing the exposure light amount on the substrate on the basis of a variation in transmittance of the incident light amount incident to the projection optical system. Moreover, the exposure light amount control method is characterized by the step of controlling the exposure light amount on the substrate by varying at least one of a scanning velocity of the reticle and the substrate, a timing of emitting the pulse light, an intensity of the pulse light, and a magnitude of the scanning directional of the pulse light.

Furthermore, the present invention provides the exposure method for projecting an image of the pattern onto the substrate through the projection optical system by illuminating the pattern on the reticle, the exposure method being characterized by the step of computing the exposure light amount on the substrate and the step of accumulating the exposure light amount and terminating the exposure as the accumulated exposure light amount has reached a predetermined exposure light amount.

In addition, the present invention provides the

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exposure light amount control apparatus for controlling the exposure light amount for projecting and exposing the pattern on the reticle onto the substrate through the projection optical system, the exposure light amount control

5 apparatus comprising a memory section for saving a variation in transmittance of the projection optical system and a control unit for computing the exposure light amount on the substrate on the basis of the variation in transmittance saved in the memory section.

10 The present invention further provides the manufacture method for manufacturing circuit elements by illuminating the pattern on the reticle and projecting an image of the pattern on the substrate through the projection optical system, the manufacture method being characterized by

15 controlling the exposure light amount on the substrate on the basis of a variation in transmittance of the projection optical system.

The present invention utilizes the concept that the variation in transmittance from the start of irradiation of

20 a laser light indicates a predetermined variation amount in accordance with the amount of irradiation. The total exposure light amount on the photosensitive substrate can be controlled, for instance, by measuring the variation in transmittance and saving it in advance and computing the

25 light amount on the photosensitive substrate sequentially and accumulating the light amounts, while the incident light amount incident to the projection optical system from the start of exposure, i.e., from the start of irradiation of

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the laser light upon the actual exposure, by multiplying the incident light amount by the variation in transmittance saved. Therefore, the present invention can compute the light amount irradiated on the photosensitive substrate

5   always with high precision during a period of time from the start of the exposure to the termination of the exposure and control the accumulated exposure light amount on the photosensitive substrate, even if the transmittance of the projection optical system would vary with the exposure light

10   amount.

The present invention is directed to the device manufacture method for manufacturing devices, including the step of illuminating the mask with the exposure light of ultraviolet rays through the illumination optical system and

15   projecting a device pattern on the mask onto the photosensitive substrate through the projection optical system, the method comprising the first step of deciding to determine whether an amount of an attenuation factor (a transmittance or transmissivity of the illumination optical

20   system and the projection optical system) of a light amount from the illumination optical system and the projection optical system varies or not, the second step of irradiating the projection optical system with the exposure light for a predetermined period of time, when it is decided in the

25   first step that the attenuation factor (transmittance) varies, and the third step of projecting the device pattern onto the photosensitive substrate after the second step.

The present invention is further directed to the

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projection exposure apparatus for carrying out an actual

exposure that comprises illuminating the mask with the

illumination optical system supplying the exposure light of

an ultraviolet region and projecting the device pattern on

5   the mask onto the photosensitive substrate by means of the

projection optical system, the projection exposure apparatus

being provided with a control means for controlling the

illumination optical system by deciding to determine whether

the transmittance of the illumination optical system and the

10   projection optical system varies and by irradiating the

illumination optical system and the projection optical

system with the exposure light for a predetermined period of

time prior to the actual exposure, when it is decided that

the transmittance of the illumination optical system and the

15   projection optical system varies.

In accordance with the present invention, the control

means provided in the projection exposure apparatus is so

adapted as to confirm a status of the projection exposure

apparatus and a history of the status thereof, prior to

20   starting the operation of the actual exposure. The control

means is saved with a condition in which a state of

attachments on a lens surface (a reflecting surface) of the

optical system varies, and the condition is associated with

the status of the projection exposure apparatus and the

25   history thereof. Further, the control means is adapted to

irradiate the optical system (the illumination optical

system and the projection optical system) of the projection

exposure apparatus with a light source of light having a

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wavelength substantially equal to the exposure light, prior to the start of the operation of the actual exposure, when the confirmed status and history agree with the saved condition as a result of comparison of the confirmed status and history with the saved condition. This removes the attachments of foreign materials, etc. on the surface of the optical system, so that the exposure light amount can be controlled with high precision because an output of a sensor for sensing the exposure light amount corresponds to the exposure light amount on the photosensitive substrate in order to stabilize the transmittance of the optical system ranging from the sensor for sensing the exposure light amount disposed in an intermediate position of the projection optical system to the photosensitive substrate.

It is to be noted herein that, as it is preferred that the time for irradiation of the optical system of the projection exposure apparatus with a light varies with a state of the attached materials, the control means is preferably saved with information relating to the time for irradiation with the light that is associated with the status of the projection exposure apparatus and the history thereof.

A description will be made of the condition in which the state of the attached materials varies.

The conditions of a variation in the state of the attached materials include, among others:

(1) No irradiation of the optical system of the projection exposure apparatus with the exposure

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light or the like for a predetermined period of time;

(2) Changes of the condition for illumination;

(3) Exchanges for reticles (masks);

(4) Practice of maintenance;

(5) Termination of the operation of an air conditioning device;

(6) Termination of the operation of an entire exposure apparatus;

(7) Variation in a state of an atmosphere around the illumination optical system and the projection optical system;

(8) Variation of transmittance of the illumination optical system and the projection optical system themselves;

(9) Changes of optical characteristics of the projection optical system; and

(10) Changes of a reflectance of the surface of a photosensitive substrate.

A description will now be made of the instance in which, as the condition (1) above, the optical system of the projection optical system is not irradiated with an exposure light or the like for a predetermined period of time or longer. In this instance, there is the risk that transmittance of the optical system itself is decreased to a lower level than the time when the irradiation has been previously been effected, because there is the possibility that foreign materials etc. would be attached in an amount

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larger than they have been at the previous irradiation. Moreover, in this instance, the extent to which the foreign materials etc. attached are removed as the irradiation with the actual exposure light starts and develops, so that the

5   risk may be caused to occur that the controls of the exposure light amount suffer from the difficulty due to a fluctuation of the transmittance of the optical system itself in accordance with the irradiating period of time. Therefore, in order to compete with the difficulty, the

10   attached foreign materials etc. are removed by irradiating the optical system with the light prior to the actual exposure, so that the transmittance of the optical system is improved to stabilize the transmittance of the optical system. In this instance, it is preferred that a duration

15   during which the irradiation of the optical system has been suspended is determined and the period of time for irradiating the optical system with the light before the actual exposure is adjusted in accordance with the determined duration. This configuration can avoid the

20   irradiation with the light more than necessary, so that the duration of the irradiation with light can be shortened and damages against the optical system can be minimized.

Then, a description will be made of the instance where the condition (2) for illumination is changed. The

25   illumination conditions may include, for example, a state of a distribution of images of a light source on a pupil plane (for example, a large σ value, a small σ value, a zonal illumination, a special oblique illumination, etc.). In

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such an instance, the way of passage of a light flux passing through the inside of the optical system changes, so that a distribution of the intensity of the light may vary with each portion of the optical system. Therefore, the effect

5   to be achieved by removal of the attached materials, etc. by the irradiation with light may vary with each portion of the optical system, so that the risk may be caused to occur that the transmittance of the entire optical system may fluctuate. For instance, when the illumination condition is changed

10   from a small σ value to a large σ value, there may be the instance where no attached materials are removed at a portion where no light flux passes upon the actual exposure and yet where the light flux passes upon the actual exposure at the large σ value. There is the risk that the

15   transmittance of the optical system may fluctuate upon the actual exposure at the large σ value.

Therefore, in the case of the condition (2) above, too, the attached materials are removed by the irradiation of the optical system with light prior to the actual exposure, so

20   that the transmittance of the optical system can be improved and the transmittance of the optical system can be stabilized. In this instance, the optical system can be stabilized in a more effective way by investigating illumination conditions prior and after the change of the

25   illumination condition and adjusting the duration of the irradiation with light prior to the start of the actual exposure in accordance with a combination of the illumination conditions investigated. In such an instance,

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if the illumination condition is changed, for example, from the small σ value to the large σ value, the irradiation would not be required.

The condition (3) above where the reticles (masks) are exchanged will be described. The pattern formed on the reticle varies with kinds of reticles, so that the state in which a diffraction light is created from the pattern varies for each kind of the reticle. At this time, the way of passage of the light flux passing through the inside of the projection optical system varies, so that a distribution of the intensity of the light varies at each portion of the projection optical system. Therefore, the effect to be produced by the removal of the attached materials by means of the irradiation with light may vary at each portion of the projection optical system, so that the risk may occur such that the transmittance of the entire projection optical system is caused to fluctuate. Accordingly, in this instance, too, the attached materials are removed by irradiation of the optical system with light prior to the actual exposure, so that the transmittance of the optical system is improved and the transmittance of the optical system is stabilized. At this time, it is preferred that the projection exposure apparatus is further provided with an ID number reading device for reading an ID number formed on a reticle and database for the reticle. With this configuration, the duration for the irradiation with light prior to the start of the actual exposure can be adjusted in accordance with the kind of the reticle prior and after the

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exchange, thereby stabilizing the optical system in a more effective way.

A description will be made of the condition (4) above where maintenance has been performed. During maintenance, coverings for the optical system and other parts may be detached, so that the atmosphere inside the optical system is exchanged for the ambient atmosphere outside the optical system. As a result, there is the possibility that a concentration of attaching foreign materials etc. in the atmosphere inside the optical system may vary. Further, at this time, the risk may occur such that the transmittance of the optical system may be caused to fluctuate from the previous irradiation, due to attachment or detachment of the attached materials to or from the optical system. In this instance, too, the attached materials etc. are to be removed by the irradiation of the optical system with light prior to the actual exposure, thereby improving the transmittance of the optical system and as a result stabilizing the transmittance of the optical system. In this case, it is preferred that a covering or other part is provided with a switch for deciding to determine whether the maintenance has been performed or not. Moreover, it is preferred to vary a duration for the irradiation with light prior to the start of the actual exposure in accordance with a duration of time when the covering is being kept open by accumulating the open duration or otherwise. This configuration can stabilize the optical system in a more efficient way. If the duration when the covering has been kept open is shorter

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than a particular duration, the irradiation prior to the exposure can be omitted.

Then, a description will be made of the condition (5) where the operation of the air conditioning device is suspended. Under this condition, the state of the atmosphere around the optical element constituting the illumination optical system and the projection optical system changes, so that the risk may occur that the state of attached materials etc. may be changed. In this instance, too, the attached materials are removed by irradiation of the optical system with light prior to the actual exposure, thereby improving the transmittance of the optical system and consequently stability the transmittance of the optical system. Upon this irradiation with light, it is preferred to adjust the duration of the irradiation with light prior to the actual exposure in accordance with the period of time during which the operation of the air conditioning device has been suspended.

A description will be made of the condition (6) where the operation of the entire system of the projection exposure apparatus has been suspended. Under this condition, the irradiation of the laser light has been suspended as in the case of the condition (2) above and the operation of the air conditioning device has been suspended as in the case of the condition (5) above, so that the risk may occur such that the state of the attached materials, etc. fluctuates. In this instance, too, the attached materials etc. are removed by the irradiation of the optical system with light

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prior to the actual exposure, so that the transmittance of the optical system is improved and as a result the transmittance of the optical system is stabilized. Upon this irradiation with light, it is preferred to adjust the

5   duration of the irradiation with light prior to the actual exposure in accordance with the period of time during which the operation of the exposure apparatus has been suspended.

Moreover, a description will be made of the condition (7) where the state of the atmosphere around the

10   illumination optical system and the projection optical system has been changed. The state of the atmosphere may include, for example, a temperature, moisture or pressure of the atmosphere, a flow rate of gases flowing inside the optical system in a state that the illumination optical

15   system and the projection optical system has been closed in an airtight fashion, among others. In the case where the state of the atmosphere has varied in such a manner, there is the risk that the state of the attached materials, etc. has changed, too, so that the irradiation with light is to

20   be effected prior to the actual exposure. Upon this irradiation with light, it is preferred that the duration for the irradiation with light prior to the actual exposure be adjusted in accordance with a degree of the change of the atmosphere.

25   Now, a description will be made of the case under the condition (8) where the transmittance of the illumination optical system and the projection optical system themselves has been changed. It is to be noted herein that, in each of

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the cases of the conditions (1) to (7), inclusive, the state of the attached materials etc. is regarded as being changed when the projection exposure apparatus has been brought into a particular state, however, the configuration can be modified so as to detect a pollution of the optical system and to make a decision as to whether the irradiation with light should be effected or not prior to the actual exposure on the basis of a result of detection of the pollution. Such a configuration may include, for example, a direct measurement of the transmittance of the illumination optical system and the projection optical system themselves, a measurement of a sample for use in measuring a transmittance thereof, disposed at a position in the vicinity of those optical systems, and a measurement of a concentration of pollutants in the atmosphere around those optical systems. In this configuration, for instance, the irradiation with light is to be effected prior to the actual exposure to stabilize the optical systems, when the transmittance of the optical system is lower than a predetermined value, or when the concentration of the pollutants exceeds a predetermined value, or when a value obtained by integrating the concentration of the pollutants by time is larger than a predetermined value. In addition, the duration of the irradiation with light prior to the actual exposure can be adjusted in accordance with the transmittance measured or the concentration of the pollutants measured.

Further, a description will be made of the condition (9) where the optical characteristic of the projection

optical system has been changed. For instance, in the case

where a size of an opening diaphragm in the projection

optical system is changed in a manner as will be described

hereinafter or where a pupil filter is inserted or detached,

5   there is the risk that the state of the attached materials

etc. is changed, too. In such an instance, the irradiation

with light is effected prior to the actual exposure.

In addition, a description will be made of the

condition (10) where the reflectance on the surface of the

10   photosensitive substrate has been changed. In this instance,

the light amount of the light to be returned to the surface

of the photosensitive substrate upon the actual exposure is

changed, too, so that the effect to be achieved upon the

actual exposure by the removal of the attached materials,

15   etc. may produce different effects. In this instance, the

transmittance of the optical system also varies, so that the

irradiation with light is effected prior to the actual

exposure, thereby stabilizing the optical system.

The present invention is further directed to the

20   projection exposure apparatus having a light source for

generating an exposure light having a wavelength of a

ultraviolet region, an illumination optical system for

leading the exposure light from the light source to a

pattern on the mask, and a projection optical system for

25   forming an image of the pattern on the mask in a

predetermined exposure region on a photosensitive substrate,

the projection exposure apparatus comprising a memory means

for saving information relating to a variation in a

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distribution of transmittances resulting from passage of the
exposure light from the light source through at least the
projection optical system; an illuminance distribution
adjustment means for adjusting a distribution of illuminance
5   in the exposure region; and a control means for controlling
the illuminance distribution adjustment means so as to
maintain the distribution of illuminance in the exposure
region on the basis of the information from the memory means,
the control means being connected to the memory means and
10   the illuminance distribution adjustment means.

The information relating to the variation in the
distribution of illuminance saved in the memory means for
use in accordance with the present invention is not
restricted to the variation in the distribution of
15   transmittance and may include any information corresponding
to a variation in the distribution of transmittance. In
accordance with the present invention, as the information
relating to the variation in the distribution of
transmittance, it is preferred to use, for example,
20   information relating to a distribution of illuminance in the
exposure region.

In a first preferred mode of the embodiment of the
present invention, the projection exposure apparatus is
further provided with a measurement means for measuring the
25   distribution of illuminance in the exposure region, wherein
the control means amends at least a portion of the
information from the memory means on the basis of the
information from the measuring means and controls the

illuminance distribution adjustment means on the basis of the information so amended.

In this configuration, an amendment on the basis of the information from the measuring means is made at predetermined number of times per unit time, and the predetermined number of times of amendments may preferably be determined in accordance with a magnitude of the amount of the variation per unit time of the distribution of transmittance saved in the memory means.

In a second preferred mode of the embodiment of the present invention, the information on the variation in the distribution of transmittance is saved in the memory means in association with at least one of a period of time during which the exposure light passes through the illumination optical system and the projection optical system, a condition for illuminating the mask, a kind of masks, an optical characteristic of the projection optical system, and a light amount of the light reflected at the photosensitive substrate and returned to the projection optical system.

In a third preferred mode of the embodiment of the present invention, the memory means is arranged so as to save information relating to the variation in the distribution of transmittance resulting from passage of the light through the illumination optical system.

Moreover, the present invention provides the projection exposure apparatus having a measurement means for measuring the distribution of illuminance in the exposure region by means of the exposure light through the mask, a

memory means for saving information relating to the distribution of illuminance in the exposure region by means of the exposure light through the mask in a predetermined initial state, an illuminance distribution adjustment means for adjusting the distribution of illuminance in the exposure region, and a control means for controlling the illuminance distribution adjustment means for maintaining the distribution of illuminance in the exposure region at a constant level on the basis of a result of measurement by the measurement means and the information from the memory means.

In this configuration, the information relating to the distribution of illuminance in the memory means may preferably be information relating to a distribution of illuminance in the exposure region in a state in which the distribution of transmittance of the mask (the distribution of reflectance in the case of a reflective mask) is uniform. The state in which the distribution of transmittance of the mask is uniform, so referred to herein, may also include, for example, a state in which the mask is detached from the light path.

The projection exposure apparatus according to the present invention in the configuration as described above is adapted to acquire a variation in the distribution of transmittance of the illumination optical system and the projection optical system, which results upon passage of the exposure light from the light source through the illumination optical system and the projection optical

system on the basis of an experiment in advance and save the variation in the distribution of transmittance in the memory means. Upon the actual exposure, a distribution of transmittance in the exposure region is estimated on the

5   basis of the information saved in the memory means, and the illuminance distribution adjustment means is controlled so as to correct an irregularity of illuminance in the exposure region resulting from the distribution of transmittance. In this configuration, the irregularity of illuminance can be

10 corrected without measuring the irregularity of illuminance on the exposure region even if the actual exposure is being effected.

At this time, the distribution of illuminance in the exposure region may be measured at a predetermined time

15 interval and an estimated value of the distribution of transmittance in the exposure region may be amended on the basis of a result of measurement. This allows the estimated value of the distribution of transmittance in the exposure region to become closer to an actual value on the basis of

20 the result of measurement, thereby further improving a precision of the correction of the irregularity of illuminance.

The time interval referred to herein may be set to become a shorter interval when an amount of the variation in

25 the distribution of transmittance per unit time is larger and to become a longer interval when the amount of the variation in the distribution of transmittance per unit time. This allows an improvement in precision of the correction of

the irregularity of illuminance without increasing the number of measurements so much (in other words, without decreasing a throughput).

In the instance as shown in Fig. 31, the variation in the distribution of transmittance is based on only the period of time (the period of time during which no exposure light passes) during which the exposure light passes through the illumination optical system and the projection optical system, as a parameter. As a parameter for causing the distribution of transmittance to vary, an illumination condition may also be used, in addition to the period of time during which the exposure light has passed through the illumination optical system and the projection optical system. This configuration will be described hereinafter with reference to Fig. 32. In Fig. 32, there is shown a state of a light flux passing through a projection optical system PL. Further, Fig. 32 shows the state of the light flux in the case of the large σ value, as shown in Fig. 32(a), in the case of the small σ value, as shown in Fig. 32(b), and in the case of a modified illumination such as a zonal illumination or a special oblique inclination illumination, etc, as shown in Fig. 32(c). Moreover, in Figs. 32(a) to (c), the light flux on the axes ranging from the point on the light axis of the projection optical system PL in the reticle R is indicated by hatching the area, and the main light rays intersecting with the light axis at the position of an opening diaphragm AS is indicated by broken line. As is apparent from Figs. 32(a) to 32(c), the

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position of the light flux passing through the projection

optical system PL may vary with the condition (large σ

value, small σ value, and a varied illumination) of

illuminating the reticle R, and the distribution in

5 intensity of the light flux of each of the optical elements

constituting the projection optical system PL may vary (in a

strict sense, it may vary in the illumination optical

system). Therefore, the attached materials, etc. to be

removed by passage of the exposure light through the

10 illumination optical system and the projection optical

system at the time of exposure are not removed in a uniform

manner at each of the optical elements and are removed in an

irregularly distributed manner. Accordingly, as shown in

Figs. 33 and 34, the distribution of variations in

15 transmittance may vary with the illuminating condition.

Fig. 33 shows a variation in transmittance in the case

of the small σ value as indicated in Fig. 32(b), and Fig.

34 shows a variation in transmittance in the case of a

varied illumination as shown in Fig. 32(c). In each of Figs.

20 33 and 34, the Y-axis represents transmittance (%) and the

X-axis represents the coordinate on an image plane (a wafer

plane) in a meridional section in which the light axis is

set as an original point. Figs. 33(a) and 34(a) show each a

distribution of transmittance in the reference state; Figs.

25 33(b) and 34(b) show each the state after the exposure has

been suspended for a predetermined time (duration A); Figs.

33(c) and 34(c) show each the state in which the exposure

light has passed through the optical system for a

predetermined time (duration B) after the state as shown in Figs. 33(b) and 34(b); Figs. 33(d) and 34(d) show each the state in which the exposure light has passed through the optical system for a predetermined time (duration C) after

5   the state as shown in Figs. 33(c) and 34(c); and Figs. 33(e) and 34(e) show each the state in which the exposure light has passed through the optical system for a predetermined time (duration D) after the state as shown in Figs. 33(d) and 34(d).

10   The variation in the distribution of transmittance of the illumination optical system and the projection optical system, which results from passage of the exposure light through the illumination optical system and the projection optical system may also be changed by a parameter other than

15   the time during which the exposure light has passed through the illumination optical system and the projection optical system.

It is thus preferred that the variation in the distribution of transmittance of the illumination optical

20   system and the projection optical system resulting from passage of the exposure light through the illumination optical system and the projection optical system is saved in association with a least one of parameters as will be described hereinafter. For the entire projection exposure

25   apparatus, at least one of the parameters is detected and information saved in the memory means corresponding to a result of detection is read, thereby controlling the illuminance distribution adjustment member on the basis of

the information.

The parameters include, among others:

(1) A time during which the exposure light passes
    through the illumination optical system and the
    projection optical system;

(2) An illuminating condition for illuminating a mask
    (a magnitude of a σ value, a zonal illumination,
    and a special oblique illumination);

(3) A kind of a mask (a density of patterns, etc.);

(4) An optical characteristic of the projection
    optical system (a size of an opening diaphragm,
    an ambient environment (pressure, temperature,
    moisture, an environment of purge, a presence or
    absence of a filter, etc.); and

(5) A light amount reflected at a photosensitive
    substrate and returned to the projection optical
    system (corresponding to a reflectance of a
    wafer).

In another mode of the projection exposure apparatus
according to the present invention, the distribution of
illuminance is measured by the exposure light through the
mask (reticle) in a state in which the illumination optical
system and the projection optical system are located each in
a predetermined condition and the measured distribution in
illuminance is saved in the memory means, in order to
measure the distribution of illuminance in the exposure
region in a state in which the mask (reticle) is loaded. In
this configuration, an actual distribution of illuminance

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can be determined by comparing the distribution of

illuminance measured in the state in which the mask is

loaded with the distribution of illuminance saved in the

memory means. The projection exposure apparatus in another

5   mode according to the present invention can provide the

advantages that the time required for measurement can be

shortened and further a throughput can be improved, because

the distribution of illuminance in the exposure region can

be measured without departing the mask from the light path.

10   The information relating to the distribution of

illuminance to be saved in the memory means may be saved in

accordance with classifications, for example, each of kinds

of the masks and each of kinds of illumination conditions.

The such information is read from the memory means in

15   accordance with the kinds of the masks loaded on the

apparatus or the illuminating conditions, upon making a

comparison of the kinds and the illuminating conditions. In

the case of a scanning exposure apparatus, the state of

diffraction light generated from a mask may vary in

20   accordance with the position of the illumination region on

the mask, and the distribution of illuminance by the

exposure light through the mask may vary, too. Therefore,

the information in the memory means may preferably be

associated with the scanning position (the position of the

25   mask with respect to the illumination region), because the

distribution of illuminance by the exposure light through

the mask may vary.

It can be noted herein that, upon measurement in

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advance, for instance, there is used a mask having no

pattern uniform in a distribution of transmittance, or the

measurement may be effected in a state in which the mask is

detached from the light path.

5   BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

Fig. 1 is a view showing a brief configuration of a

projection exposure apparatus which uses an exposure light

amount control method according to a first embodiment of the

present invention.

10   Fig. 2 is a view showing a variation of transmittance

of the projection optical system with an elapse of time.

Fig. 3 is a view showing procedures for controlling an

exposure light amount upon exposure in the exposure light

amount control method according to this embodiment of the

15   present invention.

Fig. 4 is a view showing a brief configuration of a

projection exposure apparatus according to a second

embodiment of the present invention, using an exposure light

amount control method.

20   Fig. 5 is a view for explaining details of an

operation section 45 in Fig. 4.

Fig. 6 is a view showing a flow of steps for

manufacturing semiconductor elements.

Fig. 7 is a view showing schematically a projection

25   exposure apparatus according to a third embodiment of the

present invention.

Fig. 8 is a view showing the configuration of a stage

portion of the projection exposure apparatus as shown in

Fig. 7.

Fig. 9 is a view for explaining techniques for measuring a transmittance according to a modification in a mode of the embodiment of the present invention.

5   Fig. 10 is a view showing a brief configuration of a projection exposure apparatus according to a fourth embodiment of the present invention.

Fig. 11 is a view showing an example of an illuminance distribution adjustment means of the projection exposure

10   apparatus of Fig. 10.

Fig. 12 is a view showing a configuration of a reticle stage of the projection exposure apparatus of Fig. 10.

Fig. 13 is a view showing a configuration of an X-Y stage of the projection exposure apparatus of Fig. 10.

15   Fig. 14 is a schematic construction view showing a relationship of the reticle stage with the X-Y stage of the projection exposure apparatus of Fig. 10.

Fig. 15 is a view showing an example of a measurement means of the projection exposure apparatus of Fig. 10.

20   Fig. 16 is a view showing a configuration of a projection optical system of the projection exposure apparatus of Fig. 10.

Fig. 17 is a flow chart showing an example of an exposure sequence of the projection exposure apparatus of

25   Fig. 10.

Fig. 18 is a view for explaining techniques for adjusting a distribution of illuminance for the projection exposure apparatus of Fig. 10.

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Fig. 19 is a table showing an example of a history table of the projection exposure apparatus of Fig. 10.

Fig. 20 is a table showing an example of a history table of the projection exposure apparatus of Fig. 10.

Fig. 21 is a table showing an example of a history table of the projection exposure apparatus of Fig. 10.

Fig. 22 is a table showing an example of a history table of the projection exposure apparatus of Fig. 10.

Fig. 23 is a flow chart showing an example of a sequence of an illuminance distribution adjustment of the projection exposure apparatus of Fig. 10.

Fig. 24 is a view showing a periodical variation by irradiation of illuminance at a certain one point on an exposure region.

Fig. 25 is a view showing another example of the measurement means of the projection exposure apparatus of Fig. 10.

Fig. 26 is a view showing a brief configuration of the projection exposure apparatus according to a fifth embodiment of the present invention.

Fig. 27 is a view showing the configuration of a reticle stage of the projection exposure apparatus of Fig. 26.

Fig. 28 is a view showing the configuration of an X-Y stage of the projection exposure apparatus of Fig. 26.

Fig. 29 is a view showing a portion of the measurement means of the projection exposure apparatus of Fig. 26.

Fig. 30 is a view showing an example of the

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illuminance distribution adjustment means according to
another embodiment of the present invention.

Fig. 31 is a view showing a manner of a variation in
distribution of transmittance.

Fig. 32 is a view showing a state of a light flux
passing through the projection optical system PL.

Fig. 33 is a view showing a variation in transmittance
in a state as shown in Fig. 32(b).

Fig. 34 is a view showing a variation in transmittance
in a state as shown in Fig. 32(c).

BEST MODE FOR CARRYING OUT THE INVENTION

A description will be made of an exposure light amount
control method according to the first embodiment of the
present invention with reference to Fig. 1 to 3. Fig. 1
shows a brief configuration of the projection exposure
apparatus of a step-and-repeat type, which uses the exposure
light amount control method according to the first
embodiment of the present invention. Fig. 2 shows a
periodical variation of transmittance of the projection
optical system. Fig. 3 shows the procedures of the controls
of the exposure light upon exposure in the exposure light
amount control method according to this embodiment.

In Fig. 1, the illumination light emitting from an
illumination light source 1 composed of KrF excimer laser (a
wavelength of 248 nm) or ArF excimer laser (a wavelength of
193 nm) passes through an illumination optical system 2,
composed of an input lens 21, a fly-eye lens 22, a relay
lens system 23a, a relay lens system 23b and a condenser

lens 24, and so on, and irradiates an entire area of a circuit pattern drawn on the reticle R at a uniform light amount. The illumination light passed through the reticle R on a reticle stage RST is incident to a projection optical

5   system 3 and condensed to form an image of a circuit pattern on an imaging plane of the projection optical system 3. The projection optical system 3 may be of a reflection-refraction type or of a refraction type, and the projection optical system 3 comprises an optical element made of quartz

10 or fluorite.

A wafer holder 12 for holding a wafer W by means of vacuum adsorption or any other means is disposed on the imaging plane side of the projection optical system 3. The wafer holder 12 is held on a wafer stage 6 that is disposed

15 so as to be movable in a direction substantially perpendicular to the light flux of the projection optical system 3, and moved by a drive system (not shown) in the light flux direction of the projection optical system 3, thereby enabling the surface of the wafer W to agree with

20 the imaging plane of the projection optical system. Further, the wafer stage 6 can be transferred in a two-dimensional direction perpendicular to the light flux of the projection optical system 3, thereby enabling a predetermined exposure region of the wafer W to be transferred to an imaging

25 position of the projection optical system 3. Moreover, the wafer stage 6 is provided on its upper surface with a sensor 7 for measuring the passed light amount of the illumination light passed through the projection optical system 3. The

passed light amount measurement sensor 7 is aligned in a

projection region of the projection optical system 3 by

transferring the wafer stage 6 to measure the passed light

amount of the illumination light passed through the

5   projection optical system 3. The passed light amount

measured by the passed light amount measurement sensor 7 is

transmitted to a transmittance measurement device 8.

On the other hand, a half mirror 14 is disposed in the

light path of the illumination optical system 2, and the

10   illumination light is branched by the half mirror 14. A

portion of the illumination light branched by the half

mirror 14 is then incident to an incident light amount

measurement sensor 4 for measuring an incident light amount.

The incident light amount measurement sensor 4 then outputs

15   a signal in accordance with the intensity of the incident

light to an incident light amount measurement device 5. The

incident light amount measurement device 5 gives the

incident light amount of the illumination light incident to

the projection optical system 3, on the basis of the

20   intensity of the light obtained by the incident light

measurement sensor 4, and the given incident light amount is

input in a transmittance measurement device 8.

The transmittance measurement device 8 is configured

such that a transmittance of the projection optical system 3

25   is determined from the passed light amount of the

illumination light passed through the projection optical

system 3, which is obtained by the passed light amount

measurement sensor 7, and from the incident light amount of

the incident light incident to the projection optical system 3, which is obtained by the incident light amount measurement device 5.

Fig. 2 is a graph showing the relationship of the incident light amount of the illumination light incident to the projection optical system 3 with the transmittance of the projection optical system 3. In Fig. 2, the Y-axis represents the transmittance and the X-axis represents time for irradiation of the laser light. The curved line indicating the transmittance in this figure is given as a value obtained by dividing the output of the passed light amount measurement sensor 7 by the output of the incident light amount measurement sensor 4, and plots a variation in the transmittance that varies in a state in which the laser beams are turned on and off under the substantially identical conditions as at the time of exposure. The transmittance varies slightly within a very short period of time whenever the laser is turned on and off, however, when the variation is shown in a macro way as in this figure, it can be found that the transmittance tends to decrease during the period of time ranging from the start of irradiation of the laser light to 500 seconds and then it tends to increase thereafter up to 3,000 seconds. The decrease of the transmittance after the start of irradiation of the laser light is considered to be based on properties of a lens material for each of the lens elements of the projection optical system 3, and the increase of the transmittance thereafter is considered to be caused by the cleaning action

by the excimer laser light, which removes attached materials such as water and other pollutants attached to each optical element in the projection optical system 3.

The transmittance measurement device 8 outputs a transmittance variation characteristic of the projection optical system 3 with respect to a time elapse to a transmittance variation memory device 10 for saving the transmittance variation characteristic through an exposure light amount control unit 9 on the basis of the curved line indicating the variation in transmittance, as shown in Fig. 2, and the transmittance variation characteristic of the projection optical system 3 is saved by means of the transmittance variation memory device 10. It is now to be noted herein that, although the time for irradiation of the laser light is given ob the X-axis in this embodiment, a number of irradiated pulses of the laser light or a total amount of irradiated energy can be used instead, and a curved line indicating a variation of transmittance obtained by using such a parameter can also be used for the identical purposes.

The exposure light amount control unit 9 can compute a light amount of the light arrived at the wafer W plane from the incident light amount of the illumination light incident to the projection optical system 3 during the exposure obtained by the incident light amount measurement device 5 and from the transmittance of the projection optical system 3. The resulting light amount is sequentially accumulated after the start of exposure, and the radiation and the

suspension of the radiation of the ArF excimer laser light from the illumination light source 1 are controlled so as to terminate the exposure as the accumulated light amount reaches a predetermined value. The exposure light amount

5   control unit 9 is connected to a main control unit 11 for controlling the entire system of the projection exposure apparatus. The main control unit 11 manages the state of each part of the device and to make a decision, for instance, as to whether the alignment of the wafer stage has been

10   finished, and it provides the exposure light amount control unit 9 with a signal for starting the exposure when it is decided that the wafer stage has already been aligned and the device is ready for exposure.

Fig. 3 shows the procedures for controlling the

15   exposure light amount, and a description will be made of the procedures for controlling the exposure light amount on the basis of the exposure light amount control method according to the embodiment of the present invention, with reference to Fig. 3.

20   First, a variation in transmittance of the projection optical system 3 is measured prior to the exposure to the wafer W in accordance with the procedures from step S1 to step S6. The main control unit 11 transfers the wafer stage 6 to locate the passed light amount measurement sensor 7 in

25   a projection region of the projection optical system 3. Then, the exposure light amount control unit 9 starts emission of laser light from an excimer laser of the illumination light source 1 on the basis of an instruction

from the main control unit 11 (step S2). As the

illumination light has been emitted from the illumination

light source 1, the light amount is measured on both of the

incident side and the leaving side of the projection optical

5   system 3 by the incident light amount measurement sensor 4

and the passed light amount measurement sensor 7,

respectively, in a state that the reticle R is not loaded

thereon (step S3).

        The incident light amount and the passed light amount

10   so measured are then sent to the transmittance measurement

device 8, and the transmittance measurement device 8 gives a

transmittance of the projection optical system 3 by dividing

the passed light amount by the incident light amount (step

S4). At step S5, it is then decided to determine whether

15   the measurement has been conducted at a predetermined number

of times, and the process is returned to step S3 for

effecting an additional measurement for a next transmittance,

when it is decided that the measurement is not yet conducted

at the predetermined number of times. Once the measurement

20   has been conducted at the predetermined number of times and

the transmittance has been given for the predetermined times

of measurements, then the value for each transmittance is

saved in the transmittance variation memory device 10,

together with information on the time measured (i.e., an

25   elapse of time after the start of emission of the laser

light) (step S6). The resulting variation of transmittance

of the projection optical system 3 indicates a predetermined

variation of transmittance in accordance with the irradiated

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light amount of the illumination light.

The interval of measurement is set so as to become small enough for an error in the exposure light amount, which is acceptable for the variation of transmittance as described above at the measurement interval. Further, the measurement for a variation in the transmittance at the procedures from step S3 to step S6 is not always required to be effected before the start of exposure of the wafer W at every exposure, and the such measurement is sufficient at the time when the operation of the projection exposure apparatus is started or at an appropriate time interval (for example, once per day or at every time of checking an interval between the center of a pattern of the reticle R and the center of an alignment sensor (not shown), i.e. a so-called baseline checking)).

Once the variation in transmittance of the projection optical system 3 has been determined in the manner as described above, then the process is transferred to the operation of the exposure of the wafer W (step S10). Once the exposure of the wafer W has been started on the basis of an instruction from the main control unit 11, the illumination light is emitted from the illumination light source 1 (step S11). A portion of the illumination light is then incident to the incident light amount measurement sensor 4, and the incident light amount of the illumination light incident to the projection optical system 3 is computed by the incident light amount measurement device 5 on the basis of the output of the incident light amount

measurement sensor 4 (step S12).

The incident light amount computed is then sent to the exposure light amount control unit 9, and the exposure light amount control unit 9 measures an elapse of time after the

5   start of exposure (step S13). The exposure light amount control unit 9 reads data of the transmittance at the corresponding time elapse from the measured data on the variation in transmittance in a time series of the projection optical system 3 saved in the transmittance

10   variation memory device 10 measured by the procedures starting with step S1 and ending with step S6 (step S14), and the light amount on the current wafer W surface is computed on the basis of a result of the current measurement of the incident light amount and the value of the

15   transmittance read (step S15). The frequency of this computation is set to be substantially equal to the intervals of measurement as described above. The computation of the light amount on the wafer W surface in the above manner is repeated, and a value close to the light

20   amount on the wafer W surface is obtained always at the current point of time.

Further, the exposure light amount control unit 9 accumulates the light amount on the wafer W surface determined in the manner as described above sequentially

25   from the start of exposure (step S16), and determines as to whether the accumulated exposure light amount reaches a predetermined accumulated exposure light amount by comparing the accumulated exposure light amount with the accumulated

exposure light amount determined in advance from a
sensitivity of a resist or the like on the wafer W (step
S17). If the accumulated exposure light amount would not
reach the predetermined accumulated exposure light amount,
5   the process returns to step S12 from which the procedures
for measuring the incident light amount are to be repeated.

Once the accumulated exposure light amount has reached
the predetermined accumulated exposure light amount, the
exposure light amount control unit 9 suspends the emission
10   of the laser light from the excimer laser of the
illumination light source 1 (step S18), and the exposure for
one shot is finished (step S19). Then, if a shot region
would be left non-exposed, the main control unit 11
transfers the wafer stage 6 in a predetermined distance to
15   transfer the wafer W to a next shot position at which the
processes from step S11 to step S19 are repeated for
exposing the shot region of the wafer W, and the process has
been finished when the exposure of all the shot regions on
the wafer W has been completed (step S20).

20   Next, a description will be made of the exposure light
amount control method in the second embodiment of the
present invention, with reference to Figs. 4 and 5. In this
embodiment, a description will be made of the case in which
the exposure light amount control method according to the
25   present invention is applied to a scanning projection
exposure apparatus of a so-called step-and-repeat type, in
which a scanning exposure for effecting the exposure by
transferring the reticle stage RST and the wafer stage 6 in

synchronism with each other is combined with a stepping

operation. The scanning projection exposure apparatus of

the step-and-scan type for use in this embodiment differs

from the projection exposure apparatus of the step-and-scan

5   type according to the first embodiment of the present

invention in that the accumulated exposure light amount can

be controlled by controlling the scanning velocity, making

the number of pulses variable, and so on.

The scanning projection exposure apparatus of the

10   step-and-scan type is disclosed in Japanese Patent

Application Laid-Open No. 6-232,030, and a brief

configuration of the scanning projection exposure apparatus

of the step-and-scan type will be described hereinafter with

reference to Fig. 4. As shown in Fig. 4, a laser light

15   (having a wavelength of 250 nm or less) emitting from the

light source 1 of a pulse oscillation type, such as, e.g.,

KrF excimer laser or ArF excimer laser, has its sectional

beam form shaped by a beam shaping optical system 32 so as

to become efficiently incident to a fly-eye lens 34

20   connected thereto, the beam shaping optical system 32 being

composed of a cylinder lens, a beam expander, and so on.

The laser light leaving from the beam shaping optical system

32 is incident to a light extinction means 33 which in turn

comprises a coarse adjustment section and a fine adjustment

25   section of transmittance. The laser light leaving the light

extinction means 33 is incident to a fly-eye lens 34.

The fly-eye lens 34 is to illuminate a vision field

diaphragm 37 disposed behind and the reticle R at a uniform

illuminance. The laser light leaving from the fly-eye lens 34 is incident to a beam splitter 35 having a small reflectance and a large transmittance, and the laser light passed through the beam splitter 35 illuminates a vision field diaphragm 37 at a uniform illuminance through a first relay lens 36. The shape of an opening portion of the vision field diaphragm 37 in this embodiment may be, for example, a rectangle, or the like.

The laser light passed through the vision field diaphragm 37 travels through a second relay lens 38, a turning mirror 39 and a main condenser lens 40 and then illuminates the reticle R on a reticle stage 41 at a uniform illuminance. The vision field diaphragm 37 and the pattern-forming surface of the reticle R are conjugated with each other, and the laser light is irradiated on a slit-shaped rectangular illumination region 56 on the reticle R conjugated with the opening portion of the vision field diaphragm 37. The shape of the opening portion of the vision field diaphragm 37 may be changed through a drive section 42 to adjust the shape of the slit-shaped illumination region 56.

The pattern image in the slit-shaped illumination region 56 on the reticle R is projected and exposed to the wafer W through the projection optical system 3. The reticle stage 41 is scanned in the X-direction by a reticle stage drive section 43, when the Z-axis is set so as to become parallel to the light axis of the projection optical system 3, and the scanning direction of the reticle R with

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respect to the slit-shaped illumination region 56 and on a
flat plane perpendicular to the light axis thereof is set as
an X-direction. The reticle stage drive section 43 is
controlled by an operation section 45 operable by an

5   instruction of the main control system 11 for controlling
the operation of the entire system of the device.

On the other hand, the wafer W is loaded on an XY-
stage 48 that can be scanned at least in the X-direction (in
the left-and-right direction in Fig. 4) through a wafer

10 holder 47. Although, illustration of a Z-stage for
alignment of the wafer W in the Z-direction, and so on is
omitted in Fig. 4, they are disposed between the XY-stage 48
and the wafer stage 47. The wafer W is scanned in the -X-
direction by means of the XY-stage 48 in synchronism with

15 scanning the reticle R in the X-direction, and the like.
The operation of the XY-stage 48 is driven by a wafer stage
drive section 49. The XY-stage 48 is loaded thereon with
the passed light amount measurement sensor 7.

The laser light reflected at the beam splitter 35 is

20 received by the incident light amount measurement sensor 4
and supplied to the operation section 45 which in turn is
provided with the incident light amount measurement device 5,
the transmittance measurement device 8, the exposure light
amount control unit 9, and the transmittance variation

25 memory device 10, as shown in Fig. 5.

The main control unit 11 can adjust an output power of
the illumination light source 1, as needed, and a
transmittance in the light extinction means 33. The

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operator can input information of a pattern of the reticle R

to the main control unit 11 through the input-output means

54, information of a variation in transmittance of the

projection optical system 3, and so on, and the main control

5   unit 11 is provided with a memory 55 for storing a variety

of information.

Then, a description will be made of the exposure light

amount control method in this embodiment of the present

invention, in which the scanning projection exposure

10 apparatus having the configuration as described above is

used. First, when one point on the wafer W loaded on the

wafer holder 47 is considered, the light amount determined

by the sensitivity of the resist and so on for a period of

time during which the one point passes through a projection

15 field of the projection optical system controls the velocity

of the stage during the exposure so as to irradiate the

point with the light. This can be represented briefly by

the formulas as will be described hereinafter.

The exposure time t (in second) can be represented by

20 the following formula:

$$t = S/I = D/v \qquad (1)$$

where the illuminance on an exposure plane (the

illuminance on the image plane) of the wafer W is indicated

by I (mW/cm^2); the desired exposure light amount (a

25 sensitivity of a photosensitive material on the wafer W) is

indicated by S (mJ/cm^2); the width in the scanning direction

on the exposure plane of the wafer W in the slit-shaped

illumination region is indicated by D (mm); and the scanning

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velocity of the reticle R and the wafer W, when translated into the exposure plane of the wafer W, is indicated by v (mm/second).

And the pulse energy Pw on the exposure plane of the wafer W (represented in mJ/cm^2.pulse) has a relationship with a transmittance T and a pulse output PL (represented in mJ/cm^2.pulse) as follows:

$$Pw = T \times PL \qquad (2).$$

In this case, the illuminance I (mW/cm^2) on the exposure plane of the wafer W can be represented by the relationship as follows:

$$I = T \times PL \times f \qquad (3)$$

where reference symbol f represents a frequency of oscillation of the illumination light source 1 (in Hz).

Then, the pulse number N required for exposure can be represented as follows:

$$N = f \times t \qquad (4).$$

Therefore, the equation can be obtained from the formulas (1), (3) and (4) as follows:

$$N = S/(T \times PL) = D \times f/v \qquad (5).$$

From this formula (5), it is found necessary to make some controls in order to make the value obtained each by S/T x PL and D x f/v an integer.

It is to be noted herein that the projection field length D in the scanning direction is an inherent constant for each projection exposure apparatus and that the required exposure light amount S is a value to be determined by the resist used, and the like. Moreover, the passed light

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amount I of the projection optical system per unit time can
be obtained by measuring a variation in transmittance of the
projection optical system from the start of irradiation in
advance by the like procedures as have been previously

5   described in connection with the projection exposure
apparatus of the step-and-repeat type and by computing a
current light amount on a wafer surface on the basis of the
previous result of measurement, the current result of
measurement, and the time elapse measured from the start of

10   the exposure. The frequency of this computation is set so
as to become as short as possible for the exposure time for
one shot (a duration from the start of scanning to the end
of finishing scanning).

In other words, in scanning one shot region, a

15   computation of the light amount on the wafer surface is
repeated at several times to give a value close to the light
amount on the wafer surface always at the current point of
time. The stage is controlled by computing an appropriate
scanning velocity (v) at that point of time from the above

20   formulas. In this configuration as described above, the
scanning projection exposure apparatus can effect an optimal
exposure even if transmittance of the projection optical
system would vary during exposure, like the projection
exposure apparatus of the step-and-repeat type as described

25   above. In the above instances, the scanning velocity (v) is
optimized in accordance with the variation in transmittance;
however, the optimal exposure for the variation in
transmittance can be effected in accordance with the

variation in transmittance, for instance, even if the frequency (f) of an oscillating pulse of the laser light source varies with a variation in transmittance or the width (a slit width) (D) of the exposure region in the scanning

5   direction (the X-direction) varies with a variation in transmittance by making the vision field diaphragm 37 variable. Further, the optimal exposure can also be effected in accordance with the variation in transmittance by varying the pulse output (intensity) PL of the laser in

10 accordance with the variation of transmittance T so as to make the pulse energy on the exposure plane of the wafer W constant. The pulse output PL can be adjusted by controlling the voltage to be applied to the illumination light source 1 or by adjusting the light extinction means 33.

15   In the above embodiments, the variation in transmittance is measured and saved in advance by utilizing the phenomenon that the variation in the transmittance of the projection optical system from the start of irradiation with laser indicates a predetermined variation in accordance

20 with the amount of irradiation of the illumination light. Therefore, the exposure light amount on the wafer plane can be given sequentially in an accurate way from the start of exposure simply by measuring the light amount of the light incident to the projection optical system at the actual

25 exposure by using the light having a wavelength of 250 nm or less. Further, the accumulated exposure light amount can be determined accurately by accumulating the light amounts sequentially acquired in the above manner, so that a

decrease in a precision of controlling the exposure light amount can be prevented.

As shown in Fig. 2, the transmittance can be increased once it has been decreased with an elapse of time.

5 Therefore, a so-called dummy irradiation for irradiating an excimer laser is effected up to the irradiation time (for example, 500 seconds in Fig. 2) that starts increasing the transmittance on the basis of the variation in the transmittance saved, prior to the actual exposure of the

10 wafer W, and thereafter the light amount of the light on the wafer W is computed on the basis of the irradiation time, the characteristic of the periodical variation in transmittance saved, and the light amount of the light measured by the incident light amount measurement sensor 4,

15 and the exposure light amount may be controlled by using the light amount computed in the above manner.

Moreover, even if the transmittance of the projection optical system would vary by the incident light amount, the exposure light amount can be controlled with high precision

20 without measuring the light amount of the light on the wafer plane during exposure, so that it is not needed to install a new sensor for measuring the light amount of the light on the wafer plane during exposure. Therefore, this configuration has the advantage in that a space above the

25 wafer stage can be utilized more effectively, for instance, by installing sensors and so on.

Then, a description will be made of the manufacture method for manufacturing semiconductor elements, including

the exposure step using the exposure light amount control

method in the first and second embodiments of the present

invention, with reference to the flow chart as shown in Fig.

6. First, at step S100, a design of a logic circuit and a

5   pattern is drawn. Then, at step S102, a reticle R is formed

by drawing the circuit pattern for each layer on the basis

of the design drawing. Concurrently with the step of

forming the reticle R, a wafer W is prepared from a material

such as silicone or the like having a high purity, at step

10   S104, and a photoresist (a photosensitive resin) is coated

on the entire surface area of the wafer W at step S106.

Then, in an exposure process (a photolithographic

process) at step S108, the reticle R prepared at the above

step and the wafer W coated with the photoresist at the

15   above step are transferred to the exposure apparatus as

described in each of the embodiments above, and then they

are loaded, followed by sequential exposure of an image of

the pattern drawn on the reticle R to the exposure region on

the wafer W in the manner as described above and by

20   transcription of the image of the pattern thereof onto the

exposure region of the wafer W. Upon transcribing the image

of the pattern of the reticle R onto the exposure region of

the wafer W, the exposure light amount control method in the

above embodiments is used.

25   Then, at step S110, the exposed wafer W is placed in a

thermostat vessel and then immersed in a developing liquid.

This permits a resist image to be formed in such a manner

that the resist portion sensitized by the exposure light is

caused to dissolve while the resist portion non-sensitized

is left unsolved, when the photoresist is of a positive type.

The photoresist image can be formed in a reverse manner when

the photoresist is of a negative type.

5   The process further advances to step S112, an nitride

film (for example, Si_3N_4) in the region from which the

photoresist on the wafer W has been removed by patterning is

subjected to etching with an etching liquid.

Then, at step S114, a doping operation is carried out

10   for injecting a material such as, e.g., phosphorus or

arsenic, into the region of the wafer W in which the resist

has been removed for forming elements such as, e.g.,

transistors, diodes, etc. After doping, the resist on the

wafer W is removed, for example, by a plasma asher (an

15   ashing device).

Thereafter, the processes from steps S106 to S114 are

repeated to superimpose another upper circuit pattern over

the lower circuit pattern in plural layers on the surface of

the wafer W in substantially the same manner as described

20   above.

At step S116, a chip is assembled by using the wafer W

with the desired circuit patterns formed in the manner as

described above. More specifically, an aluminum electrode

is deposited on the wafer W and each of the elements is

25   connected to one another as a circuit, followed by forming a

chip. The chip so formed is then assembled by means of

steps for dicing, bonding, molding, and so on.

Then, at step S118, the semiconductor elements

prepared at step S116 are then subjected to, for example, experiments for electrical features, inspection of their structures and experiments for reliability. The semiconductor element can be prepared as a final product by

5   means of the manufacturing processes as described above (step S120).

It is to be understood that the present invention is not restricted to the embodiments and modes as described above and may encompass various modifications and variations.

10   For instance, in the first and second embodiments, the exposure light amount is arranged so as to be controlled on the basis of the transmittance characteristics of the projection optical system 3, which have been measured and saved. When the illumination light is kept being irradiated

15   onto the projection optical system 3 as shown in Fig. 2, the variation in transmittance may become small to a certain extent within short. Therefore, the exposure light amount can be controlled on the basis of the characteristics of the periodical variation in transmittance measured and saved in

20   the manner as described above, until the variation in the transmittance becomes small to that extent. The exposure light amount on the wafer W is then computed on the basis of the transmittance (a transmittance with its variation reduced to a small extent) at that time and the light amount

25   of the light measured by the incident light amount measurement sensor 4, after the amount of a variation in transmittance by irradiation of the optical elements with the laser light become smaller. Then, the exposure light

amount may be controlled by using the computed light amount. When the excimer laser is continued being irradiated until the variation in transmittance becomes small enough in the manner as described above, the exposure light amount on the

5   wafer W can be made constant.

In addition, in the case where the throughput is acceptable, the transmittance of the projection optical system 3 may be confirmed at a predetermined timing and the exposure light amount may be controlled on the basis of the

10   confirmed transmittance. For instance, the passed light amount may be measured by the passed light amount measurement sensor 7 by transferring the wafer stage 6 at the time of exchanging wafers, at the time of conducting a so-called baseline checking or at every shot, and the

15   transmittance is computed on the basis of the passed light amount measured by the passed light amount measurement sensor 7 and the light amount of the light measured by the incident light amount measurement sensor 4, thereby controlling the exposure light amount on the basis of the

20   transmittance and the light amount of the light measured by the incident light amount measurement sensor 4.

Now, a specific description will be made of the third embodiment of the present invention with reference to Figs. 7 to 9. In this embodiment, the present invention is

25   applied to the projection exposure apparatus of a step-and-scan type.

Fig. 7 shows a brief configuration of the projection exposure apparatus in this embodiment of the present

invention. In Fig. 7, the illumination light comprising

pulse laser light is emitted from an excimer laser light

source 112 with its emission state controlled by an exposure

light amount control unit 111. In this embodiment, as the

5   excimer laser light source 112, there may be used an ArF

excimer laser light source narrow-banded so as to avoid an

absorption of oxygen, having a wavelength between 192 nm and

194 nm. In this embodiment and the examples as shown in

Figs. 1 to 6, however, an exposure light source may include,

10   for example, a KrF excimer laser light source (a wavelength

of 248 nm), F_2 excimer laser light source (a wavelength of

157 nm), a metallic vapor laser light source, a higher

harmonics generating device for generating higher harmonics

of YAG laser, or a bright line lamp such as a mercury lamp,

15   etc., or the like. Moreover, the laser light source is not

restricted to a narrow-banded laser light source.

The illumination light from the excimer laser light

source 112 passes through a beam matching unit (BMU) 113,

including a beam shaping optical system for shaping the

20   section of the illumination light leaving from the excimer

laser into a predetermined shape in section, a beam expander,

and so on, and is incident to a first illumination optical

unit 115 through a variable light extinction device 114.

The variable light extinction device 114 can adjust a light

25   extinction ratio of a pulse laser light in a stepwise or

non-stepwise way in accordance with an instruction from the

exposure light amount control unit 111. The first

illumination optical unit 115 contains a first fly-eye lens

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and forms a planer light source as a secondary light source in the position in the vicinity of the leaving plane of the first fly-eye lens.

The illumination light from the first illumination optical unit 115 is incident to a second illumination optical unit 117 through a vibrating mirror 116 for preventing a formation of a speckle pattern on the reticle R or the wafer W as a plane to be irradiated. The detailed configuration and operation of the vibrating mirror 116 is disclosed, for example, in Japanese Patent Application Laid-Open No. 1-257,327 (U. S. Patent No. 4,970,546), so that the explanation of the mirror 116 is omitted herein.

The second illumination optical unit 117 contains a second fly-eye lens and forms a planar light source acting as a tertiary light source in the position in the vicinity of the leaving plane of the second fly-eye lens. An opening diaphragm unit 118 is disposed in the vicinity of the planar light source by the second illumination optical unit. The opening diaphragm unit 118 is formed with a circular opening diaphragm having a first diameter, a circular opening diaphragm for a small σ value having a diameter smaller than the first diameter, an opening diaphragm for a varied illumination (a special oblique illumination) composed of plural openings eccentric from the light axis or a zonal opening diaphragm in the form of a turret. An opening diaphragm control unit 119 controls the opening diaphragm unit 118 so as to locate one of the plural openings disposed in the form of a turret selectively in a light path.

On the leaving side of the opening diaphragm unit 118 is obliquely disposed a beam splitter 120 having a high transmittance and a low reflectance, and an integrator sensor 121 composed of photoelectrical elements such as, for example, photodiodes, etc. is disposed on the reflecting direction of the beam splitter 120. The output from the integrator sensor 121 is transmitted to the main control unit 100 in a manner as will be described hereinafter. The configuration of the integrator sensor 121 is disclosed in Japanese Patent Application Laid-Open No. 8-203,803, so that a description thereof will be omitted.

The illumination light passed through the beam splitter 120 is condensed with a third illumination optical unit 122 and illuminates an illumination vision field diaphragm unit (a reticle blind system) 123 in a superimposed manner. The illumination vision field diaphragm unit 123 is disposed in a position conjugated with the incident plane of the first fly-eye lens in the first illumination optical unit 115 and the incident plane of the second fly-eye lens in the second illumination optical unit 117. In this configuration, the illumination region in the illumination vision field diaphragm unit 123 is of a shape resembling generally the sectional shape of each of the lens elements of the second fly-eye lens in the second illumination optical unit. The illumination vision field diaphragm unit 123 is divided into a movable blind and a fixed blind. The fixed blind is a fixed vision field diaphragm having a rectangular opening, and the movable

blind comprises a pair of movable blades each being movable
in the scanning direction of the reticle R and in the
direction intersecting at a right angle with the scanning
direction thereof and being openable. The shape of the
5   illumination region on the reticle is determined by the
fixed blind, and a covering for the opening of the fixed
blind is gradually opened or closed by the movable blind at
the time of the start and the termination of the scanning
exposure. This prevents the illumination light from being
10   irradiated in a region on the wafer W other than a shot
region as an original object for exposure.

The operation of the movable blind in the illumination
vision field diaphragm unit 123 is controlled by a movable
blind drive unit 124. The main control unit 100 drives the
15   movable blind in the scanning direction in synchronism
therewith through the movable blind drive unit 124, upon
scanning the reticle R and the wafer W in synchronism with
each other in a manner as will be described hereinafter.
The illumination light passed through the illumination
20   vision field diaphragm unit 123 illuminates a rectangular
illumination region of the pattern plane (the bottom plane)
of the reticle R at a uniform illumination distribution
through a fourth illumination optical unit 125, an eccentric
mirror 126 and a fifth illumination optical unit 127. The
25   fourth and fifth illumination optical units 125 and 127 have
each the function to make the position of the fixed blind in
the illumination vision field diaphragm unit 123 and the
pattern plane of the reticle R conjugated with each other,

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and the shape of the illumination region on the reticle R is defined by the opening of the fixed blind.

The following is a description by referring to the axis on the plane parallel to the pattern plane of the reticle R and perpendicular to the paper plane of Fig. 7 as the X-axis, to the axis parallel to the paper plane of Fig. 7 as the Y-axis, and to the axis perpendicular to the pattern plane of the reticle R as the Z-axis. In this instance, the illumination region on the reticle R is a rectangular region elongated in the X-direction, and the reticle R is in turn scanned in the +Y-direction or the -Y-direction with respect to the illumination region, upon the scanning exposure. In other words, the scanning direction is set to be the Y-direction.

The pattern in the illumination region on the reticle R is reduced at a projection magnification β ($|\beta|$ being, for example, 1/4, 1/5, etc.) through the projection optical system PL that is telecentric at both ends (or at one end on the wafer side), and the pattern is projected and imaged in the exposure region on the surface of the wafer W with the photoresist coated thereon.

The reticle R is held on a reticle stage 131, and the reticle stage 131 is mounted on a guide extending in the Y-direction on a reticle support table 132 through an air bearing. The reticle stage 131 can scan on a reticle support table 132 in the Y-direction at a constant velocity by means of a linear motor, and is provided with an adjustment mechanism that can adjust the position of the

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reticle R in the X-direction, the Y-direction, and a
rotation (θ) direction. By a moving mirror 133M fixed to
the end portion of the reticle stage 131 and a laser
interferometer (no axis but Y-axis being shown) fixed to a
5   column 133 (not shown), the positions of the reticle stage
131 (the reticle R) in the X-direction and the Y-direction
are measured always at a resolution of approximately 0.001
μm, and an angle of rotation of the reticle stage 131 is
also measured. The measured values are then supplied to a
10   reticle stage control unit 134 that in turn controls the
operation of the linear motor and the like on the reticle
support table 132 in accordance with the measured values
supplied.

On the other hand, the wafer W is held on a wafer
15   holder 135, and the wafer holder 135 is mounted on a wafer
stage 136 that in turn is mounted on a guide on a base, not
shown, through an air bearing. The wafer stage 136 scans
the wafer W on the base in the Y-direction at a constant
velocity by means of a linear motor and is transferred in a
20   stepwise manner as well as is transferred stepwise in the X-
direction. Moreover, a Z-stage mechanism for transferring
the wafer holder 135 in the Z-direction in a predetermined
scope and a tilt mechanism (a leveling mechanism) for
adjusting an inclination angle of the wafer holder 135 are
25   incorporated in the wafer stage 136.

The positions of the wafer stage 136 (wafer W) in its
X-direction and Y-direction are measured always at a
resolution of about 0.001 μm by a moving mirror 137M fixed

to the side surface portion of the wafer stage 136 and a

laser interferometer (no axes but Y-axis being shown) fixed

to a column, although not shown. An angle of the rotation

of a sample table 137 is also measured. The measured values

5   are supplied to a wafer stage control unit 138 that in turn

control the operations of a linear motor for driving the

wafer stage 136, and so on, in accordance with the measured

values supplied to the wafer stage 136.

A light path extending from the excimer laser light

10   source 112 to the fifth illumination optical unit 127 is

closed in an airtight way with an illumination system cover

141. In this embodiment, the illumination system cover 141

is filled with inert gases (e.g., nitrogen, helium, argon,

etc.), and the inert gases with their oxygen content

15   controlled to an extremely low level and to a low moisture

level are supplied by means of a first gas supply unit 142

at a predetermined flow rate through a chemical filter, an

electrostatic filter, or the like. Further, a sensor 143 is

disposed within a space closed with the illumination system

20   cover 141, which sensor being to detect the state

(temperature, moisture, etc.) of the inert gases to be

filled in the light path extending from the excimer laser

light source 112 to the fifth illumination optical unit 127.

The illumination system cover 141 has a door portion

25   disposed so as to be opened or closed for readiness to

perform maintenance of an inner optical system, and a sensor

144 for detecting the opening and closing of the door

portion is disposed. The information on a flow rate of the

inert gases to be supplied from the first gas supply unit

and other information as well as the outputs from the

sensors 143 and 144 are transmitted to the main control unit

100.

5   The projection optical system PL is provided with a

variable opening diaphragm 151 which have its opening size

arranged so as to be variable, and a variable opening

diaphragm control unit 152 for controlling the variable

opening diaphragm is disposed to control the operation of

10   the opening of the variable opening diaphragm 151 on the

basis of an instruction from the main control unit 100. In

the case of adjusting the opening size of the variable

opening diaphragm 151 manually, the variable opening

diaphragm control unit 152 transmits information relating to

15   the opening size of the variable opening diaphragm to the

main control unit 100. Moreover, a pupil filter 153 is

disposed in the vicinity of the variable opening diaphragm

151 which pupil filter being to vary an eccentric state

between a light flux passing through a portion above the

20   pupil region of the projection optical system PL and a light

flux passing through another portion thereof. The pupil

filter 153 is disposed so as to transfer the position

outside and inside the light path of the projection optical

system PL selectively. This transfer operation can be

25   controlled by means of a pupil filter control unit 154 on

the basis of an instruction from the main control unit 100.

The pupil filter control unit 154 transmits information

relating to the position (inside the light path or outside

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the light path of the projection optical system PL) of the
pupil filter 153 to the main control unit 100. The
configuration of the pupil filter 153 itself is disclosed,
for example, in Japanese Patent Application Laid-Open No. 6-

5   120,110, U. S. Patent No. 5,552,856, or U. S. Patent No.
5,610,684.

The projection optical system PL is composed of plural
lens elements and provided with a second gas supply unit 155
for supplying dry inert gases into a space between the

10   plural lens elements, the dry inert gases being processed in
advance so as to reduce the oxygen content to an extremely
low level and the moisture content to a low level. The
second gas supply unit 155 is also arranged to control the
temperature, moisture, flow rate and pressure of the dry

15   inert gases to be flown into the inside of the projection
optical system PL, and the temperature, moisture, flow rate
and pressure of the dry inert gases inside the projection
optical system PL are detected by means of a sensor 156
disposed in the projection optical system PL. The output

20   from this sensor 156 is transmitted to the main control unit
100. The second gas supply unit 155 is also provided with a
chemical filter or an electrostatic filter for removing
impurities contained in the dry inert gases to be flown into
the inside of the projection optical system PL.

25   In order to control the temperature, moisture and so
on of an atmosphere around the projection optical system PL
in an accurate way, a chamber 157 is disposed around the
projection optical system PL. The chamber 157 is provided

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with a door portion, although not shown, and a sensor 158 for detecting the opening and closing of the door portion is disposed inside the chamber 157. The output from the sensor 158 is transmitted to the main control unit 100.

5   In this embodiment, in order to determine an influence of the reflected light reflected from the wafer W and returning to the projection optical system PL during the actual exposure, a beam splitter 128 having, for example, a reflectance of several percentage is interposed between the

10   third illumination optical unit and the fourth illumination optical unit in the illumination optical system, and the light to be returned through the projection optical system and the reticle R after reflection at the wafer W during the actual exposure is led to a reflectance sensor 129 composed

15   of photoelectrical detection elements such as photodiodes and so on. The reflectance sensor 129 is disposed in the position conjugated with the reticle R (conjugated with the illumination vision field diaphragm unit 123). The configuration of the reflectance sensor 129 of this type is

20   disclosed, for example, in Japanese Patent Application Laid-Open No. 8-250,398. The output from the reflectance sensor 129 is transmitted to the main control unit 100.

In this embodiment, a bar cord reader 159 is disposed in a reticle conveyer path extending from a reticle stocker

25   (not shown) to the reticle stage 131, in order to distinguish the kinds of the reticles R to be loaded on the reticle stage 131. The reticle R is recorded with information relating to ID numbers of the reticles by means

of bar cords, and the bar cord reader 159 transmits information relating to the ID numbers of the reticles to the main control unit 100.

Then, the main control unit 100 will be described.

Among information to be transmitted to the main control unit from the sensors disposed at the portions of the main body of the projection exposure apparatus, the information for use in determining whether the transmittance (an attenuation factor) of the optical system of the projection exposure apparatus will be as follows:

(1) information from the opening diaphragm control unit 118 relating to kinds of opening diaphragms;

(2) information from the integrator sensor 121 relating to the exposure light amount;

(3) information from the first gas supply unit 142 relating to the flow rate of inert gases to be flown into the illumination system cover 141;

(4) information from the sensor 143 relating to the state (temperature, moisture, etc.) of the inert gases in the illumination system cover 141;

(5) information from the sensor 144 relating to the opening and closing of the illumination system cover 141;

(6) information from the variable opening diaphragm control unit 152 relating to the opening size of the variable opening diaphragm 151;

(7) information from the pupil filter control unit 154 relating to the insertion and detachment of the pupil filter 153;

(8) information from the second gas supply unit 155 relating to the flow rate of the inert gases to be flown into the projection optical system PL;

(9) information from the sensor 156 relating to the state (temperature, moisture, etc.) of the inert gases in the projection optical system PL;

(10) information from the reflectance sensor 129 relating to the light amount of the reflected light to be returned to the projection optical system PL; and

(11) information relating to the kind of the reticle R from the bar cord reader 159.

To the main control unit 100 is connected a memory 105 which saves information relating to a variation in transmittance obtained by experiments in a form corresponding to each of the information (1) to (11), inclusive, as described above. A specific example of each of the such information will be described hereinafter.

First, as the information (1) above, information is saved which relates to a variation in transmittance when the plural openings disposed in the opening diaphragm unit 118 are shifted to one another.

As the information (2) above, a periodical variation in the relationship of the period of time during which no light is irradiated with the transmittance, in which the period of time during which the integrator sensor 121 have output is set as a irradiation with light time, because the presence or absence of the output from the integrator sensor 121 is associated with the irradiation of light to the

optical system.

As each of the information (3) and (8) above, a periodical variation in the relationship of the flown amount of the inert gases with the transmittance is saved for each of the gas supply units.

As each of the information (4) and (9) above, a periodical variation in the relationship of the state (temperature, moisture, etc.) of the inert gases with the transmittance is saved for each.

As the information (5) above, a periodical variation in the relationship of the opening and closing time of the illumination system cover 141 with the transmittance is saved.

As the information (6) above, a relationship of the opening size of the variable opening diaphragm 151 with the transmittance is saved.

As the information (7) above, information relating to a relationship of the insertion and detachment of the pupil filter 153 with the transmittance is saved.

As the information (10) above, information relating to a relationship of the output value from the reflectance sensor 129 with the transmittance is saved.

As the information (11) above, information relating to a relationship of the ID number of the reticle R with the transmittance is saved.

In this embodiment, the information relating to each of items (1) to (11), inclusive, is saved in combination with each of all the remaining items (for instance, in

combination of the information (1) above relating to each of

the kinds of the opening diaphragms with each of the

remaining information (2) to (11), inclusive). It can be

noted herein, however, that in the case where no problems

5   may be caused from a practical point of view, it is not

necessary to save the information in all combination and the

items other than the items that are not governing

transmittance may be omitted in order to reduce an amount of

memory.

10   Then, the main control unit 100 determines the

transmittance of the projection exposure apparatus at that

time on the basis of the information relating to each of the

items (1) to (11) above of the projection exposure apparatus

detected by each of the sensors and the information saved in

15   the memory 105, and makes a decision whether there is any

problem in carrying out the actual exposure. In the case

where it is decided herein that there is the problem with

the actual exposure, the light is irradiated onto the

illumination optical system and the projection optical

20   system. The cases where it is decided herein that the

actual exposure causes the problem are the instances where

there is a difference of the transmittance from a reference

transmittance by a predetermined amount or there is a

variation in transmittance between before and after the

25   shift of the openings by a predetermined amount.

        At this instance, the time and the intensity

(corresponding to the exposure light amount) for the

irradiation with light required for recovering the

transmittance are associated with the information relating
to the transmittance saved, and they are saved in the memory
105.

Then, a description will be made of the operation of
5   the main control unit 100 upon the irradiation of light.

First, the main control unit 100 gives an instruction
to the wafer stage control unit 138 to transfer the wafer
stage 136 so as for the wafer W to be evacuated from the
exposure region of the projection optical system PL in a
10 distance sufficiently apart therefrom. At this time, the
wafer stage 136 may be controlled in such a manner that the
wafer W is placed in a resting position at the wafer stage
136 before it is loaded with the wafer W. A region 136A for
absorbing light may be disposed on t the wafer stage 136,
15 for instance, as shown in Fig. 8, in order to prevent the
light leaving from the projection optical system PL from
being diffused on the wafer stage 136 or the like upon the
irradiation of the light and from exerting influences upon
the wafer W. Further, in place of the light absorbing
20 region 136A, a reflecting plane may also be disposed so as
for the light to return to the projection optical system PL.

Turning now to Fig. 7, the main control unit 100 gives
an instruction to the exposure light amount control unit 111
to minimize the light extinction rate in the light
25 extinction device 114. This can shorten the time for which
the light is being irradiated. This configuration is not
restricted to this so long as the irradiation with light is
required to the optical element constituting the light

extinction device 114.

Concerning the opening size of the opening diaphragm, the opening for use in the actual exposure after the irradiation with light may be located in the light path of

5   the projection optical system. In this instance, the main control unit 100 may provide the opening diaphragm control unit 119 with an instruction so as to allow the opening having the largest size (the largest area) among the openings set in the opening diaphragm unit 118 to be located

10 in the light path or so as to use a different opening having a σ value larger than 1 at the time of the irradiation with light prior to the actual exposure, the different opening being disposed at the opening diaphragm unit 118 separately from the opening for use in exposure.

15   Thereafter, the main control unit 100 gives the movable blind drive unit 124 an instruction to operate the movable blind in the illumination vision field diaphragm unit 123 so as to become full open. In this instance, the fixed blind in the illumination vision field diaphragm unit

20 123 may be disposed so as to be evacuated to a position outside the light path of the illumination optical system, and it can be evacuated at the time of irradiation with light prior to the actual exposure. In this embodiment, the fixed blind may be used in combination with the movable

25 blind, however, if only the fixed blind is disposed, it is preferably configured so as to be evacuated at the time of irradiation with light prior to the actual exposure. On the other hand, if only the movable blind is disposed, it is

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preferred to open it to a full extent at the time of
irradiation with light prior to the actual exposure.

Moreover, the main control unit 100 gives the reticle
stage control unit 134 an instruction to detach the reticle
R from the reticle stage 131 and operates it to locate the
opening portion of the reticle stage 131 in a position
between the illumination optical system and the projection
optical system. This operation can be effected while the
reticle R is stayed loaded on the reticle stage 131
depending upon the kind of a pattern formed on the reticle R.

In this case, the variable opening diaphragm may be
set to have an opening size for use at the time of the
actual exposure after the irradiation with light. In this
instance, the main control unit 100 sends an instruction to
the variable opening diaphragm control unit 152 so that the
opening size of the variable opening diaphragm 151 becomes
the largest opening diameter.

Next, the main control unit 100 gives an instruction
to the pupil filter control unit 154 to operate the pupil
filter 153 so as to be evacuated toward a position outside
the light path of the projection optical system PL. It is
not required to allow the pupil filter 153 to evacuate,
however, when the light is irradiated onto the pupil filter
153 itself, for instance, in the case where the pupil filter
is used at the time of the actual exposure after the
irradiation with light.

It may be possible to mix an assistant gas with the
inert gases for use in promoting the removal of the attached

materials by the irradiation with light. At this end, the main control unit 100 gives an instruction to the first and second gas supply units 142 and 153 to mix the assistance gas with the inert gases and flow the mixture into a space

5   in the illumination system cover 141 and inside the projection optical system PL. Such an assistance gas may include, for example, highly oxidative gases such as, e.g., oxygen, ozone, active oxygen or the like.

After the above operations have been finished, then

10   the main control unit 100 gives an instruction to the exposure light amount control unit 111 to oscillate the excimer laser light source 112 and irradiate the illumination optical system and the projection optical system PL with the illumination light. At this instance,

15   the light amount is detected by means of the integrator sensor 121 through the beam splitter 120, and the detected light amount is transmitted to the main control unit 100.

Then, the main control unit 100 compares the irradiation with light time from the start of the

20   irradiation with light and the light amount of the light required for recovering the transmittance, saved in the memory 105, with the time elapse from the start of the irradiation with light and the light amount of the light, detected by the integrator sensor 121, and transmits an

25   instruction to stop oscillating the excimer laser light source 112 to the exposure light amount control unit 111, when the irradiation with light time and the light amount of the light exceed the values saved therein.

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In the above operation, if the state of the inert gases in the spaces in the light extinction device 114, the opening diaphragm unit 118, the illumination vision field diaphragm unit 123, the variable opening diaphragm 151, the

5 pupil filter 153 and the illumination system cover 141 and inside the projection optical system PL is different from the state upon the actual exposure to be carried out thereafter, the main control unit 100 gives an instruction each to the exposure light amount control unit 111, the

10 opening diaphragm control unit 119, the movable blind drive unit 124, the variable opening diaphragm control unit 152, the pupil filter control unit 154, the first gas supply unit 142, and the second gas supply unit 153 to recover the state of the inert gases in the light extinction device 114, the

15 opening diaphragm unit 118, the illumination vision field diaphragm unit 123, the variable opening diaphragm 151, the pupil filter 153 and the illumination system cover 141 and inside the projection optical system PL, respectively, to the state at the time of the actual exposure.

20 In this instance, the main control unit 100 is provided with an input section 110 for implementing an input relating to the condition at the time of the actual exposure, and the condition upon the actual exposure is set in each of the units on the basis of this input or the information from

25 the bar cord reader 158 for reading the ID number of the reticle.

At the time of the irradiation with light in the manner as described above, the reticle R is loaded on the

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reticle stage 131 when the reticle R has been detached from the reticle stage 131, and it is transferred to the position at which it is subjected to the actual exposure. On the other hand, when the wafer W is located at the evacuating position, the wafer W is loaded on the wafer holder 135 of the wafer stage 136.

Thereafter, the reticle R and the wafer W are aligned relatively with each other by means of an alignment system, although not shown.

As the alignment has been completed, the main control unit 100 sends a command to start the actual exposure to the reticle stage control unit 134, the wafer stage control unit 138 and the exposure light amount control unit 111. Upon receipt of the instruction from the main control unit 100, the reticle stage control unit 134 and the wafer stage control unit 138 start scanning the wafer W at the velocity VW in the Y-direction through the wafer stage 136 in synchronism with the scanning of the reticle R at the velocity VR in the Y-direction through the reticle stage 131. Further, the exposure light amount control unit 111 starts oscillating the excimer laser light source 112. In this embodiment, the relationship of the scanning velocity of the wafer W with the projection magnification β for the wafer W is set so as to satisfy: VW = β x VR, wherein VW is the scanning velocity of the wafer W; β is the projection magnification for the wafer W; and VR is the scanning velocity of the reticle R.

In the embodiment as described above, it is decided to

determine whether the irradiation with light is to be

effected on the basis of the history of exposure. It is

possible to use different techniques, in place of the above

technique. The different techniques for use in this

5   embodiment may include, for example, the technique for

measuring the transmittance of the optical system itself,

the technique for measuring the transmittance of a sample

which in turn is disposed in a position in the vicinity of

the optical system for measurement of the transmittance; and

10   the technique for measuring a concentration of pollutants in

the atmosphere around the optical system.

As the technique for measuring the transmittance (the

attenuation factor) of the optical system itself, there may

be mentioned, for example, the technique for measuring the

15   transmittance (the attenuation factor) thereof on the basis

of a difference between the output from the integrator

sensor 121 and the output from an illuminance meter 136D

disposed on the wafer stage 136. In this instance, the

timing of measuring the transmittance may be selected at

20   least in the case of each of the conditions (1) to (10)

above. Further, in order to improve an estimated precision

of transmittance on the basis of the history of exposure,

the transmittance is measured at a predetermined timing, and

the estimated transmittance on the basis of the history of

25   the exposure may be calibrated.

The technique for locating the sample for measurement

of the transmittance may involve leading the exposure light

from the excimer laser light source 112 to a sample 160, for

example, as shown in Fig. 9, locating a beam splitter 161 and a sensor 162 on tics of the exposure light, locating a sensor 163 on the leaving side of the sample, comparing the output from the sensor 162 with the output from the sensor

5   163, determining a transmittance on the basis of the difference between the outputs. The irradiation with light is then effected on the basis of the resulting transmittance. In the configuration as shown in Fig. 9, in place of the excimer laser light source as a light source for exposure, a

10 light source having an identical wavelength may be disposed separately therefrom.

        In the example as shown in Fig. 7, the device is configured such that the irradiation with light can be effected automatically on the basis of the decision as to

15 whether the transmittance has varied or not. The device may also be configured such that, instead, a display section is disposed and an error display may be effected on the display section. In this instance, the operator can input a command through an input section 120 to permit irradiation with

20 light.

        The above description is directed to the cases where the present invention is applied to the scanning projection exposure apparatus. It is to be understood as a matter of course that the present invention can be applied to a

25 projection exposure apparatus (a stepper) of a sequential exposure type. Moreover, it is to be noted that the irradiation with light in the above embodiments can provide the effect of preventing a variation in characteristics due

to a thermal distribution of the optical system.

A description will be made of the projection exposure apparatus in the fourth embodiment of the present invention with reference to Figs. 10 to 25. The projection exposure apparatus in this embodiment is an example wherein the present invention is applied to a projection exposure apparatus of a step-and-scan type, like the projection exposure apparatus of the embodiment as shown in Fig. 7.

In Fig. 10, reference numeral 211 stands for an exposure light amount control unit, reference numeral 212 stands for an excimer laser light source, and reference numeral 213 stands for a beam matching unit (BMU). These elements have substantially the same configurations as those as shown in Fig. 7.

As the beam matching unit 213, there may be those as disclosed in Japanese Patent Application Laid-Open No. 8-293,491 or as proposed in Japanese Patent Application Laid-Open No. 8-353,022.

The illumination light passed through the beam matching unit 213 passes through a light-shielding pipe 214 and then is incident to a variable light extinction device 216 through a beam shaping optical system 215 for converting the shape of a section of the illumination light flux, composed of a cylindrical lens or a toric lens into a predetermined shape. The variable light extinction device 216 functions as a light attenuator and operates an inner drive motor in accordance with an instruction from the exposure light amount control unit 211, thereby adjusting

the light extinction rate of the illumination light in a non-stepwise or stepwise manner.

The illumination light passed through the variable light extinction device 216 has its light flux dimension expanded through a beam expander 217 and then travels toward a first fly-eye lens 218 with a plurality of lens elements integrated. As such an beam expander 217, there may be used those, for example, as proposed in Japanese Patent Application Laid-Open No. 9-19,912.

The illumination light incident to the first fly-eye lens 218 then forms a secondary light source composed of a plurality of images of the light source on the leaving side of the first fly-eye lens 218. The illumination light from the secondary light source passes through a relay optical system composed of a front group 219F and a rear group 219R and is incident to a second fly-eye lens 221. A vibrating mirror 220 for deviating the light path and preventing a speckle pattern from appearing on a surface on which light is irradiated is disposed in the light path between the front group 219F and the rear group 219R of the relay optical system.

The illumination light incident to the second fly-eye lens 220 then forms a tertiary light source (a planar light source) as an image of the plural light source images on the leaving side of the second fly-eye lens 221. The optical system that uses two such fly-eye lenses (optical integrators) is disclosed, for example, in Japanese Patent Application Laid-Open No. 1-235,289 (U. S. Patent No.

5,307,207), Japanese Patent Application Laid-Open No. 8-330,212, and Japanese Patent Application Laid-Open No. 9-6,009. In the vicinity of the position at which the tertiary light source is formed, an opening diaphragm unit

5   222 is disposed, the opening diaphragm unit 222 being composed of a plurality of opening diaphragms, like the opening diaphragm unit 118 as shown in Fig. 7, and being controlled with an opening diaphragm control unit 223.

The illumination light leaving from the opening

10   diaphragm unit 222 travels toward a condenser lens system 226 through a beam splitter 224 having a reflectance of several percentage. In this configuration, an integrator sensor 225 composed of a photoelectrical conversion element is disposed in the reflection direction of the beam splitter

15   224.

The condenser lens system 226 may be composed of, for example, from five sheets to ten and several sheets of lens elements, and disposed so as for its front side focus to be located nearly at the position of the opening diaphragm unit

20   222. The illumination light leaving from the opening diaphragm unit 222 is condensed by means of the condenser lens system 226, and illuminates a fixed blind 228B of a reticle blind unit 228 disposed in the vicinity of a rear side focus nearly uniformly in a superimposed manner.

25   In this configuration, in order to adjust an irregularity of illuminance, a portion of the plural lens elements constituting the condenser lens system 226 is disposed so as to move in the light axis direction and the

remaining is disposed so as to move in an oblique direction.
These lens elements are aligned by means of a condenser lens
system drive unit 227. This configuration will be described
with reference to Fig. 11. As shown in Fig. 11, the

5   condenser lens system 226 comprises a front group 226F and a
rear group 226R, which are disposed in this order from the
side of the second fly-eye lens 221. The front group 226F
is disposed so as to move along the light axis, and the rear
group 226R is disposed so as to rotate about one point on

10   the light axis. The condenser lens system drive unit 227
comprises a control sub-unit 227A, a drive sub-unit 227B,
and a drive sub-unit 227C. The control sub-unit 227A is to
generate a drive signal in accordance with an amount of
movement of the front group 226F and the rear group 226R of

15   the condenser lens system 226 on the basis of an instruction
from the main control unit. The drive sub-unit 226B is to
move the front group 226F in a predetermined amount along
the light axis on the basis of an instruction from the
control sub-unit 227A. The drive sub-unit 227C is to move

20   the rear group 226R in a predetermined amount along the
direction of rotation about one point on the light axis in
accordance with an instruction from the control sub-unit
227A. These configurations of the condenser lens system 226
and the condenser lens system drive unit 227 are proposed,

25   for example, in Japanese Patent Application Laid-Open No. 9-
34,378. Further, those as proposed in Japanese Patent
Application Laid-Open No. 8-353,023 may be used as the
condenser lens system 226 and the condenser lens system

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drive unit 227.

The reticle blind unit 228 has substantially the same
configuration as the illumination vision field diaphragm
unit 123 as shown in Fig. 7. Reference symbol 228A stands
5   for a movable blind, reference symbol 228B stands for a
fixed blind, and reference numeral 229 stands for a movable
blind control unit. The operations of the reticle blind
unit 228 and the movable blind control unit 229 are
disclosed, for example, in Japanese Patent Application Laid-
10   Open No. 4-196,513 (U. S. Patent No. 5,473,410).

In Fig. 10, reference numeral 230 stands for a relay
optical system, reference symbol 230F for a front group of
the relay optical system 230, reference numeral 231 for a
mirror for turning a light path, reference symbol 230R for a
15   rear group of the relay optical system 230, and reference
numeral 232 for a higher-order illuminance irregularity
adjustment unit.

The higher-order illuminance irregularity adjustment
unit 232 comprises a plurality of parallel flat panels each
20   having a different thickness and being light-passing, which
are disposed in the light path selectively so as to be
movable, or a member having no nearly refractive power,
which can vary its thickness in a continuous manner. The
higher-order illuminance irregularity adjustment unit 232
25   can adjust a higher-order irregularity of illuminance on the
reticle R or the wafer W by varying the thickness thereof in
the light path. A drive unit 233 drives the higher-order
illuminance irregularity adjustment unit 232 in accordance

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with an instruction from a main control unit 200 so as to insert one of the plural parallel flat panels of the higher-order illuminance irregularity adjustment unit 232 selectively into the light path or to make the thickness of

5   the member having no refractive power set to become a predetermined thickness. The higher-order illuminance irregularity adjustment unit 232 is disclosed, for example, in Japanese Patent Application Laid-Open No. 9-82,631.

In Fig. 10, reference numeral 234 stands for a sub-

10   chamber, and the sub-chamber 234 has substantially the same configuration as the illumination system cover 143 as shown in Fig. 7. The configuration of the such sub-chamber is disclosed, for example, in Japanese Patent Application Laid-Open No. 6-260,385 (U. S. Patent No. 5,559,584), Japanese

15   Patent Application Laid-Open No. 8-279,458, and Japanese Patent Application Laid-Open No. 8-279,459.

Further, in Fig. 10, reference numeral 235 stands for a beam splitter, and reference numeral 236 stands for a reflectance sensor, as well as the beam splitter 235 and the

20   reflectance sensor 236 have substantially the same configurations as the beam splitter 128 and the reflectance sensor 129, respectively.

The reflectance sensor 236 may be disposed on the side opposite to the integrator sensor 225 that is interposed

25   between the reflectance sensor 236 and the beam splitter 224.

In Fig. 12, there is shown a reticle stage 240 that has substantially the same configuration as the reticle stage as shown in Fig. 7. In Fig. 12, reference numeral 241

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stands for a reticle support table, reference symbols 242A
and 243A each for a moving mirror, reference numerals 246
and 247 each for a Y-axial laser interferometer, reference
symbols 242B and 243B each for a fixed mirror, reference
5   numeral 244 for an X-axial moving mirror, and reference
numeral 249 for a reticle stage control unit. The
configuration and operation of the reticle stage are
disclosed, for example, in Japanese Patent Application Laid-
Open No. 6-291,019 (U. S. Patent No. 5,464,715). As the
10   reticle stage, there may be used the reticle stage as
disclosed, for example, in Japanese Patent Application Laid-
Open No. 8-63,231.

A rectangle-shaped opening portion 240A having a size
covering an entire area of an illumination region IA is
15   disposed at a Y-directional end portion side on the reticle
stage 240 in order to measure an irregularity of illuminance
in a manner will be described hereinafter.

Returning now to Fig. 10, the projection optical
system PL is disposed under the reticle R (on the -Z-
20   directional side), which has a predetermined projection
magnification β and which is telecentric at its both ends
(on the reticle R side and the wafer W side). The
projection optical system PL is disposed so as to allow a
column 251 disposed on a base 250 to come into abutment with
25   a fringe portion F.

As the reticle R is illuminated with the illumination
light, the illumination light passes through a light-
transmitting portion of a circuit pattern of the reticle R,

and a diffraction light (including a O-th light) passed through the pattern is incident to the projection optical system PL, thereby forming a partial image of the circuit pattern in a linear slit-shaped or rectangle-shaped exposure region on the image plane side of the projection optical system. The partial image of the circuit pattern is a reduced image of a portion of the circuit pattern of the reticle R, which is superimposed on the illumination region IA. On the image plane of the projection optical system PL is disposed the wafer W as a photosensitive substrate, and a portion of the circuit pattern is transcribed on a resist layer on the surface of a portion of one shot region among the plural shot regions on the wafer W.

The wafer W is adsorbed on a wafer holder, although not shown, and the wafer holder is disposed on a focus-leveling stage 253 for adjusting the position in the light axis direction of the projection optical system PL and an inclination with respect to the light axis. A planar position detection unit 274 for detecting the position and the inclination of the light axis direction of the wafer W on the focus-leveling stage 253 is disposed under the projection optical system PL. As the planar position detection unit, there may be used the unit as disclosed, for example, in Japanese Patent Application Laid-Open No. 6-260,391 (U. S. Patent No. 5,448,332).

The focus-leveling stage 253 has a Y-stage 254 disposed so as to be movable in the Y-direction as shown in the drawing, and the Y-stage 254 has an X-stage 255 disposed

so as to be movable in the X-direction as shown in the drawing.

Fig. 13 is a perspective view showing an example of the X-Y stage as described above. In Fig. 13, reference numeral 254 stands for a Y-stage, reference symbols 254F1 to 254F4, inclusive, each for a fluid bearing, reference numeral 255 for an X-stage, and reference symbol 255A for beams. The Y-stage 254 is configured so as to be movable in the Y-direction as shown in the drawing. Further, in Fig. 13, reference symbols 255C1-255C4, inclusive, stand each for a fluid bearing, reference symbols 255B1 and 255B2 each for a transferring guide, reference symbols 256A1 and 256A2 each for a fixed guide, and reference symbols 256B1 and 256B2 each for a magnetic track. The X-stage 255 is transferred in the X-direction as shown in the drawing in association with a motor coil in the X-stage 255.

In Fig. 13, reference numeral 257 stands for a Y-axial moving mirror, reference numeral 258 for an X-axial moving mirror, reference numeral 259 for a Y-axial laser interferometer, and reference numeral 260 for an X-axial laser interferometer.

The positions in the X-direction and the Y-direction of the Y-stage 254 can be measured always at a resolution of approximately 0.001 μm by the Y-axial laser interferometer 259 and the X-axial laser interferometer 260, respectively. The displacement of rotation (about the light axis of the projection optical system PL) of the Y-stage is measured by these laser interferometers. The measured values are

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supplied to a wafer stage control unit 261. The wafer stage
control unit 261 is controlled by the main control unit 200.
The X-Y stage is disclosed, for example, in Japanese Patent
Application Laid-Open No. 8-233,964, and the X-Y stage as
5 disclosed in Japanese Patent Application Laid-Open No. 8-
31,728 can also be used. As the focus-leveling stage 253,
that as disclosed, for example, in Japanese Patent
Application Laid-Open No. 7-161,799, may be used.

At a portion on the Y-stage 254 are disposed a reticle
10 coordinates system and a reference mark plate 254A, the
reticle coordinates system being defined by the coordinates
to be measured by the laser interferometers 246 to 248,
inclusive, on the reticle side, and the reference mark plate
254a corresponding to a wafer coordinates system defined by
15 the coordinates to be measured by the laser interferometers
259 and 260 on the wafer side. At a position in the
vicinity of the reference mark plate 254a on the Y-stage 254
is disposed a light receipt section 254B of an illuminance
meter for measuring a distribution of illuminance in the
20 exposure region EA. The configuration of the reference mark
plate 254a is disclosed, for example, in Japanese Patent
Application Laid-Open No. 7-176,468 (U. S. Patent No.
5,646,413).

As shown in Fig. 14, a first reference mark for the
25 reference mark plate 254a is provided above the reticle R
(on the +Z-directional side). Moreover, reticle alignment
microscopes 262 and 263 are disposed, too, which allow an
observation of a mark provided on the reticle R together

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with the first reference mark. Further, turning mirrors 264

and 265 are disposed, which lead the detection light from

the reticle R to the reticle alignment microscopes 262 and

263, respectively, the turning mirrors 264 and 265 being

5   movably disposed so as to be inserted or detached in a

position inside or outside the light path of the

illumination light travelling toward the reticle R from the

illumination optical system. As an exposure sequence has

been started in a manner as will be described hereinafter,

10   mirror drive units 266 and 267 evacuate the respective

turning mirrors 264 and 265 from the light path in response

to an instruction from the main control unit 200. An

alignment unit 268 of an off-axis type for observing an

alignment mark (a wafer mark) formed on the wafer W is

15   disposed on the side surface in the Y-direction of the

projection optical system PL. On the other hand, the

reference mark plate 254A is provided with a second

reference mark corresponding to the first reference mark, in

order to allow a measurement of a baseline amount defining a

20   distance between the reference position of the projection

optical system PL and the alignment unit 268 of the off-axis

type.

The reticle alignment microscopes 262 and 263 are then

associated with the reticle coordinates and the wafer

25   coordinates system.

Then, a description will be made of the configuration

of the illuminance meter with reference to Fig. 15, in which

Fig. 15(a) is an enlarged view showing an enlarged portion

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in the vicinity of the light receipt section 254B on the Y-stage 254, and Fig. 15(b) is a plan view showing the Y-stage 254. In Fig. 15(a), the light receipt section 254B comprises a plate-shaped member provided with a plurality of

5   pinholes 254B1 to 254B5, inclusive. Each of the pinholes 254B1 to 254B5 is connected to an optical fiber 254D1 to 254D5, respectively, which each leads the light received through each of the pinholes 254B1 to 254B5. The optical fibers 254D1 to 254D5, inclusive, are each made of a

10   material (for example, quartz glass, etc.) having a transmittance for the exposure light, and lead the light from the light receipt section 254B to a light delivery section 254C on the Y-stage 254. The light delivery section 254C is provided with a plurality of opening portions 254C1

15   to 254C5, inclusive, and the plural opening portions 254C1 to 254C5 are connected to an leaving end of each of the respective optical fibers 254D1 to 254D5, inclusive.

     As shown in Fig. 15(b), the projection optical system PL is provided at its side with a detection section 254E for

20   detecting the light from the light delivery section 254C. The detection section 254E comprises a relay optical system 254E1 for forming an image of the light delivery section 254C and a photoelectrical conversion element 254E2 disposed at the position of the image of the light delivery section

25   254C. The photoelectrical conversion element 254E2 is formed at its plural locations with light spots corresponding to the light incident to the plural opening portions 254B1 to 254B5, inclusive. Then, the

photoelectrical conversion element 254E2 converts each light

spot in a photoelectric mode in accordance with the light

amount thereof and sends the output to the main control unit

200.

5   The detection section 254E is configured, as shown in

Fig. 15(c), such that the detection section 254E is aligned

so as to be superimposed right over the light delivery

section 254C in such a state that the center of the

projection optical system PL (the position of the light

10   axis) is superimposed right over the light receipt section

254B. It is to be noted herein that, although Fig. 15

indicates an example where five opening portions are

provided, the number of the opening portions, i.e. the

number of detection points for detecting a distribution of

15   illuminance, is not restricted to five, as a matter of

course. The such configuration of the light receipt section

is disclosed, for example, in Japanese Patent Application

Laid-Open No. 10-74,680 and 10-293,677.

In the example as described above, it is shown that

20   the light from the light receipt section 254B is led to the

light delivery section 254C by means of the optical fibers.

It can be noted that a turning mirror and a relay optical

system can also be used, in place of the configuration as

shown in the above example.

25   Further, in the example as described above, it is

shown that the photoelectrical conversion element 254E2 is

disposed outside the X-Y stages 254 and 255, however, the

photoelectrical conversion element 254E2 may be disposed

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inside the Y-stage 254. This configuration can provide the advantage in that the probability of causing an error in detection by the optical system extending from the light receipt section 254B to the photoelectrical conversion

5 element 254E2 can be made smaller.

Now, turning to Fig. 16, the projection optical system PL is shown which comprises a plurality of lens elements L1 to L16, inclusive, each being made of a material (for example, SiO_2, CaF_2, etc.) having a transmittance for the

10 illumination light (the exposure light) from the excimer laser light source 212, lens frames C1 to C16, inclusive, for holding the respective lens elements L1 to L16, spacers S1 to S16, inclusive, each being disposed between the respective lens frames C1 to C16 to hold the respective lens

15 elements L1 to L16 at a predetermined distance, and a barrel LB for accommodating the lens frames C1 to C16 and the spacers S1 to S16 therein. Moreover, in the first embodiment of the present invention, the projection optical system has parallel flat panels P1 and P2, each being made

20 of a material having a transmittance for the exposure light, disposed in the positions of the barrel LB closest to the reticle R side and the wafer side, respectively, thereby providing a closed space that blocks and closes the inside of the barrel LB airtight from the outside atmosphere.

25 Lines 269A to 269D are connected to the barrel LB, inclusive. Inert gases, such as dry nitrogen (N_2), which have the oxygen content to be controlled to an extremely low level, are supplied to the inside of the barrel LB, i.e., into a

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space each between the lens elements, through the lines 269A to 269D from a gas supply unit 270. The gas supply unit 270 has further the function of controlling the pressure among the intervals between the lens elements inside the barrel LB,

5   and can adjust the pressure among the intervals between the lens elements in accordance with information from the main control unit 200. The adjustment of the pressure in the manner as described above is disclosed, for example, in Japanese Patent Application Laid-Open No. 60-78,416 (U. S.

10   Patent No. 4,871,237).

A variation or fluctuation of transmittance may be caused by attachment of various impurities to the surfaces of the optical elements (e.g., lens elements L1 to L16, parallel flat panels P1, P2, etc.), which may be derived

15   from various substances present inside the barrel LB, the various substances including, for example, materials constituting the lens elements, coating materials for coating the surfaces of the lens elements, adhesive for joining the lens elements to the lens frames, paints for

20   preventing of reflection on coarsely polished surfaces of the lens elements, metallic and ceramic materials constituting the barrel, etc. Therefore, in order to reduce the variation in transmittance due to the attachment of such impurities, it is preferred that such impurities are removed,

25   for example, by means of a chemical filter, an electrostatic filter or the like, while the dry nitrogen gas with its temperature controlled is forcibly flown inside the barrel LB by means of the gas supply unit 270.

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Further, in the projection optical system PL as shown in Fig. 16, an opening diaphragm AS is configured such that its opening dimension is variable. The opening diaphragm unit 271 adjusts the opening dimension of the opening

5   diaphragm AS in response to information relating to the opening dimension of the projection optical system PL from the main control unit 200. The barrel LB is provided inside with sensors 272A to 272D, inclusive, for sensing the state (pressure, temperature, moisture, etc.) of the atmosphere

10   inside the barrel LB, and the outputs from the sensors 272A to 272D are sent to the main control unit 200. It is to be noted herein that, although the projection optical system PL as shown in Fig. 11 is directed to the number of sensors as described above, i.e., four sensors 274A to 274D, the

15   present invention is not restricted to such a particular number and any appropriate number of sensors may be used, as needed.

Moreover, the projection optical system PL as shown in Fig. 16 is configured such that all the lens elements L1 to

20   L16 are accommodated in one barrel LB, but the projection optical system PL may be of a configuration in such a manner that the lens elements L1 to L16 are divided each into an appropriate number and accommodated into an appropriate number of barrels, as disclosed, for example, in Japanese

25   Patent Application Laid-Open No. 7-86,152.

In addition, as the projection optical system PL in the embodiments of the present invention, there may be used the projection optical system of a refraction type as

proposed, for example, in Japanese Patent Application Laid-Open No. 10-79,345 or the projection optical system of a reflection-refraction type as proposed, for example, in Japanese Patent Application Laid-Open No. 8-171,054 (U. S. Patent No. 5,668,672) and Japanese Patent Application Laid-Open No. 8-304,705 (U. S. Patent No. 5,691,802).

Now, turning back to Fig. 10, the projection exposure apparatus in the fourth embodiment of the present invention is shown therein, which is provided with a bar code reader 273, like in the case as shown in Fig. 7, for distinguishing the kinds of the reticles R to be loaded on the reticle stage 240.

Then, a description of an example of the exposure sequence of the projection exposure apparatus in the fourth embodiment of the present invention with reference to the flow chart of Fig. 17.

In the flow chart as shown in Fig. 17, at step S210, various exposure conditions are set by the main control unit 200 in order to subject shot regions on the wafer W to scanning exposure at an appropriate exposure light amount. The techniques for setting the appropriate exposure conditions will be described hereinafter. The main control unit 200 sends an instruction to an exposure control unit 211 for controlling the excimer laser light source 212 and the variable light extinction device 216 on the basis of the set exposure conditions.

Each one of the shot regions on the wafer W is subjected to scanning exposure at step S210 in the manner as

described above.

Then, a description will be made of the setting of the
exposure condition at step S210. As the technique for
controlling the exposure light amount in the fourth

5   embodiment of the present invention, there may be used the
technique as disclosed, for example, in Japanese Patent
Application Laid-Open No. 8-250,402. The technique as
disclosed therein comprises computing an accumulated
exposure light amount of the pulse light irradiated until

10   then at every irradiation with the pulse light, determining
an average value of the accumulated exposure light amount so
computed and an average pulse energy, and adjusting the
accumulated exposure light amount so as to become closer to
a target accumulated exposure light amount on the basis of

15   the average value of the accumulated exposure light amount
and the average pulse energy, in order to reduce a
fluctuation or deviation of the exposure light amount among
the shot regions (the wafers) due to a fluctuation of the
energy of the pulse laser light from the excimer laser light

20   source 212.

In the fourth embodiment, the above technique is
different from the technique as disclosed in Japanese Patent
Application Laid-Open No. 8-250,402 in that the target
accumulated exposure light amount is multiplied by a

25   variation portion of the transmittance as a coefficient.
Now, a description will be made of the way of determining
the coefficient by the variation portion of the
transmittance. It should be noted herein that the operation

for correcting an irregularity of illuminance is also described hereinafter because the operation for correcting the irregularity of illuminance has to be taken into account, too, upon determining the such coefficient.

5   Fig. 18 is a series of graphs for explaining the operations for correcting the irregularity of illuminance, in which Fig. 18(a) shows a state of the irregularity of illuminance on the exposure region EA of the wafer W; Fig. 18(b) shows a distribution of illuminance to be generated in

10   order to correct the irregularity of illuminance; Figs. 18(c) to 18(e) show each a state in which the distribution of illuminance of Fig. 18(b) is divided into three components of the distribution of illuminance; and Fig. 18(f) shows a state after the correction of the irregularity

15   of illuminance. In each of Figs. 18(a) to 18(f), the Y-axis represents the intensity of light, and the X-axis represents the coordinate along the meridional direction on the wafer plane. The original point on the X-axis is the position of the light axis of the projection optical system PL.

20   First, in the exposure region EA of the wafer W, the distribution of illuminance is supposed to be as shown in Fig. 18(a). In order to make the distribution of illuminance of Fig. 18(a) flat, the distribution of illuminance to be generated by the condenser lens system 226

25   and the higher-order illuminance irregularity adjustment unit 232 is an inverted characteristic as shown in Fig. 18(b). The distribution of illuminance of the inverted characteristic as shown in Fig. 18(b) can be considered as

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three divisions into which the inverted characteristic of Fig. 18(b) is divided, i.e., the first division being the distribution of illuminance of an concave-convex component, as shown in Fig. 18(c); the second division being the distribution of illuminance of an inclining component, as shown in Fig. 18(d); and the third division being the distribution of illuminance of a higher-order component, as shown in Fig. 18(e).

The control sub-unit 227A of the condenser lens system drive unit 227 sends to the drive sub-unit 227B an instruction to transfer the front group 226F of the condenser lens system 226 to the position at which the distribution of illuminance as shown in Fig. 18(c) is to be generated, while it sends to the drive sub-unit 227C an instruction to transfer the rear group 226R of the condenser lens system 226 to the position at which the distribution of illuminance as shown in Fig. 28(d) is to be generated. The drive unit 233 for driving the higher-order illuminance irregularity adjustment unit 232 determines the thickness of the parallel flat panel (the thickness of the member having no refraction power) so as to generate a distribution of illuminance as shown in Fig. 18(e) and inserts the parallel flat panel of that thickness into the light path (or adjust the thickness of the member having no refraction power).

Although the distribution of illuminance as shown in Fig. 18(f) can be obtained in the procedures as described above, it is found that, when the intensity of the light at the original point of the distribution of illuminance in

this instance (corresponding to the average light intensity on the exposure region EA because the distribution is flat) is taken into account, the transmittance of this optical system is varied by a variation amount κ as compared with

5   the transmittance of the optical system is 100%, due to the influence of the transmittance of the optical system extending from the beam splitter 226 branching the light into the integrator sensor 225 to the projection optical system PL.

10   The variation amount κ may vary with the history of irradiation (a history of the exposure light passing through the illumination optical system and the projection optical system), as will be described hereinafter. Therefore, in the fourth embodiment, the exposure light amount is

15 controlled on the basis of the target accumulated exposure light amount modified by multiplying the target accumulated exposure light amount by the portion of the variation amount κ as a coefficient δ.

        Moreover, in the fourth embodiment of the present

20 invention, the memory 210 in the main control unit 200 is saved with the relationship among the history of irradiation, the corrected amounts, and coefficients δ for modification of the target accumulated exposure light amount as a history table. In this embodiment, the condition for illumination

25 is determined primarily for each kind of the reticle R, so that a table relating to the irradiation time and a table relating to the irradiation stop time are used, the table relating to the irradiation duration time in which the

correction amount Δ26F for the front group 226F, the

correction amount Δ26R for the rear group 226R, the

correction amount Δ32 for the higher-order illuminance

irregularity adjustment unit 232, and the coefficient δ for

5 correction of the target accumulated exposure light amount

are saved for the correction of the irradiation duration

time, and the table relating to the irradiation suspension

time in which the correction amount Δ26F for the front group

226F, the correction amount Δ26R for the rear group 226R,

10 the correction amount Δ32 for the higher-order illuminance

irregularity adjustment unit 232, and the coefficient δ for

correction of the target accumulated exposure light amount

are saved for the correction of the irradiation suspension

time. The tables of the irradiation duration time and the

15 irradiation suspension time are shown in Figs. 19 and 20,

respectively. The irradiation duration time so referred to

herein is meant to denote the period of time during which

the exposure light travels through the illumination optical

system and the projection optical system, while the

20 irradiation suspension time so referred to herein is meant

to denote the period of time during which no exposure light

travels through the illumination optical system and the

projection optical system. Further, in the tables relating

to the irradiation duration time and the irradiation

25 suspension time, the correction amount and the coefficient

at every predetermined unit time are saved. The time

interval of the unit time corresponds to the interval of the

pulse signals by a timer section disposed in the main

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control unit 200. The correction amounts $\Delta26F$, $\Delta26R$ and $\Delta32$ are not each an absolute amount of variation from the predetermined original point, but an amount of variation when the state just before one in the unit times is set as

5   the original point. In this instance, it is not preferred to set the absolute amount of variation from the predetermined original point because there is the risk that an amount of information on the coefficients for modifications as described above may become too large.

10   At this time, however, it is necessary to change the correction amount of each of the front group 226F, the rear group 226R and the higher-order illuminance irregularity adjustment unit 232 and the coefficient δ therefor in accordance with the magnitude of the energy of the exposure

15   light passing through the illumination optical system and the projection optical system PL. In the fourth embodiment of the present invention, coefficients ε, ζ, η, and ι for modifying the correction amount of the front group 226F, the correction amount of the rear group 226R, the correction

20   amount of the higher-order illuminance irregularity adjustment unit 232 and the coefficient δ, respectively, in the form corresponding to the intensity of the exposure light (corresponding to the energy of the exposure light) to be detected by the integrator sensor 225, are saved in an

25   irradiation energy modification table, as shown in Fig. 21.

Further, the transmittance of the projection optical system PL and the illumination optical system may be changed in the ascent direction by the phenomenon that the exposure

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light from the projection optical system PL is returned again to the projection optical system PL by the reflection of the wafer W itself. Therefore, there may be the case where the state of the variation in transmittance may vary by the reflectance of the wafer W. Therefore, in the fourth embodiment of the present invention, each of the correction amounts and the coefficient δ saved in the table relating to the irradiation duration time among the history tables are modified in accordance with the light amount of the light travelling through the projection optical system PL and the illumination optical system in a reverse direction after the reflection at the wafer W. Thus, coefficients ξ, ρ, τ, and χ are saved in a wafer reflectance modification table, as shown in Fig. 22, which coefficients are to modify the correction amount of the front group 226F, the correction amount of the rear group 226R, the correction amount of the higher-order illuminance irregularity adjustment unit 232, and the coefficient δ, in the form corresponding to the intensity (corresponding to the reflectance in the case of the wafer W) of the returning light to be detected by the reflectance sensor 236.

The memory 210 is provided with temporary memory sections, i.e. a first temporary memory section M1 to an eighteenth temporary memory section M18, inclusive, in addition to the irradiation duration time table, the irradiation suspension time table, the irradiation energy modification table and the wafer reflectance modification table. These temporary memory sections M1 to M18 can

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function each as a register.

Now, a description will be made of the adjustment of the irregularity of illuminance using the irradiation duration time table, the irradiation suspension time table, the irradiation energy modification table and the wafer reflectance modification table, with reference to the flow chart as shown in Fig. 23.

First, at step S301, the main control unit 200 is provided with zero (0) as a count number N in the first temporary memory section M1 in the memory 210.

Then, at step S302, count 1 is added to the count number N entered in the first temporary memory section M1 in accordance with the pulse signal by the timer section in the main control unit 200.

At the next step S303, the main control unit 200 decides whether the integrator sensor 225 outputs or not. When it is decided that the integrator sensor 225 have output, then the program goes to step S304. On the other hand, when it is decided that there is no output from the integrator sensor 225, the program goes to step S315.

The following is a description of the case where it is decided that there is the output from the integrator sensor 225.

In this instance, at step S304, the value S25 of the photoelectrical conversion output from the integrator sensor 225 is saved in the second temporary memory section M2, and the value S36 of the photoelectrical conversion output from the reflectance sensor 236 is saved in the third temporary

memory section M3.

At step S305, each of the coefficient δ, the correction amount $\Delta 26F$, the correction amount $\Delta 26R$, and the correction amount $\Delta 32$ corresponding to the value of the count number N saved in the first temporary memory section M1 is read from the irradiation duration time table. Then, the coefficient δ is saved in the fourth temporary memory section M4, the correction amount $\Delta 26F$ in the fifth temporary memory section M5, the correction amount $\Delta 26R$ in the sixth temporary memory section M6, and the correction amount $\Delta 32$ in the seventh temporary memory section M7.

Then, the program goes to step S306 at which the coefficient ε for modifying the coefficient δ, the coefficient ζ for modifying the correction amount $\Delta 26F$, the coefficient η for modifying the correction amount $\Delta 26R$, and the coefficient ι for modifying the correction amount $\Delta 32$, each corresponding to the output S25 saved in the second temporary memory section M2, are read from the irradiation energy modification table. Then, the coefficient ε is saved in the eighth temporary memory section M8, the coefficient ζ in the ninth temporary memory section M9, the coefficient η in the tenth temporary memory section M10, and the coefficient ι in the eleventh temporary memory section M11.

Further, the program goes to step S307 at which the coefficient ξ for modifying the coefficient δ, the coefficient ρ for modifying the correction amount $\Delta 26F$, the coefficient τ for modifying the correction amount $\Delta 26R$, and the coefficient χ for modifying the correction amount $\Delta 32$,

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each corresponding to the output S36 saved in the third

temporary memory section M3, are read from the irradiation

energy modification table. Then, the coefficient ξ is saved

in the twelfth temporary memory section M12, the coefficient

5   ρ in the thirteenth temporary memory section M13, the

coefficient τ in the fourteenth temporary memory section M14,

and the coefficient χ in the fifteenth temporary memory

section M15.

Then, at step S308, the coefficient δ saved in the

10   fourth temporary memory section M4 is multiplied by the

coefficient ϵ saved in the eighth temporary memory section

M8 and the coefficient ξ saved in the twelfth temporary

memory section M12 to give a modified coefficient that is

then entered in the fourth temporary memory section M4. The

15   modified coefficient is then sent to the exposure light

amount control unit 211.

At step S309, a modified correction value $\Delta 26Fc$ is

obtained by multiplying the correction amount $\Delta 26F$ saved in

the fifth temporary memory section M5 by the coefficient ζ

20   saved in the ninth temporary memory section M9 and the

coefficient ρ saved in the thirteenth temporary memory

section M13, and the modified correction value $\Delta 26Fc$ is

saved in the fifth temporary memory section M5.

At step S310, the correction amount $\Delta 26R$ saved in the

25   sixth temporary memory section M6 is multiplied by the

coefficient η saved in the tenth temporary memory section

M10 and the coefficient τ saved in the fourteenth temporary

memory section M14 to give a modified correction amount

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Δ26Rc, and the modified correction amount Δ26Rc is saved in the sixth temporary memory section M6.

Then, at step S311, the correction amount Δ32 saved in the seventh temporary memory section M7 is multiplied by the coefficient ι saved in the eleventh temporary memory section M11 and the coefficient χ saved in the fifteenth temporary memory section M15 to give a modified correction amount Δ32c, and the modified correction amount Δ32c is then saved in the seventh temporary memory section M7.

At step S312, the modified correction value Δ26Fc saved in the fifth temporary memory section M5 is added to the sixteenth temporary memory section M16. In other words, the accumulated value of the modified correction value Δ26Fc is saved as $\Sigma\Delta$26Fc in the sixteenth temporary memory section M16.

Then, at step S313, the modified correction value Δ26Rc saved in the sixth temporary memory section M6 is added to the seventeenth temporary memory section M17. In other words, the accumulated value of the modified correction value Δ26Rc is saved as $\Sigma\Delta$26Rc in the seventeenth temporary memory section M17.

Further, at step S314, the modified correction value Δ32c saved in the seventh temporary memory section M7 is added to the eighteenth temporary memory section M18. In other words, the accumulated value of the modified correction value Δ32c is saved as $\Sigma\Delta$32c in the eighteenth temporary memory section M18.

After step S314, the program advances to step S320.

The above description at steps S304 to S314 is directed to the case where there was the output from the integrator sensor 225. On the other hand, a description will be made of the case where no output was sent from the integrator sensor 225 at step S303.

In this instance, at step S315, each of the coefficient δ, the correction amount Δ26F, the correction amount Δ26R, and the correction amount Δ32 corresponding to the value of the count number N saved in the first temporary memory section M1 is read from the irradiation suspension time table. Then, the coefficient δ is saved in the fourth temporary memory section M4, the correction amount Δ26F in the fifth temporary memory section M5, the correction amount Δ26R in the sixth temporary memory section M6, and the correction amount Δ32 in the seventh temporary memory section M7.

At step S316, the coefficient δ saved in the fourth temporary memory section M4 is sent to the exposure light amount control unit 211.

Then, at step S317, the correction amount Δ26F saved in the fifth temporary memory section M5 is added to the sixteenth temporary memory section M16. In other words, the accumulated correction amount ΣΔ26F is saved in the sixteenth temporary memory section M16.

Further, at step S318, the correction amount Δ26R saved in the sixth temporary memory section M6 is added to the seventeenth temporary memory section M17. In other words, the accumulated correction amount ΣΔ26R is saved in

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the seventeenth temporary memory section M17.

Moreover, at step S319, the correction amount $\Delta 32$ saved in the seventh temporary memory section M7 is added to the eighteenth temporary memory section M18. In other words, the accumulated correction amount $\Sigma\Delta 32$ is saved in the eighteenth temporary memory section M18.

After step S319, the program goes to step S320.

At step S320, it is decided to determine whether the accumulated correction amount $\Sigma\Delta 26F$ ($\Sigma\Delta 26Fc$) saved in the sixteenth temporary memory section M16 exceeds a predetermined acceptable value. When it is decided that the accumulated correction amount does not exceed the predetermined acceptable value, then the program goes to step S322. On the other hand, when it is decided that the accumulated correction amount exceeds the predetermined acceptable value, then the program goes to step S321. The acceptable value so referred to herein corresponds to an acceptable scope of a deviation from a uniform distribution of illuminance on the wafer W, and the acceptable value can be optionally set by the operator operating the projection exposure apparatus according to the present invention.

Then, at step S321, an instruction is given to the condenser lens system drive unit 227 to transfer the front group 226F of the condenser lens system 226 by the accumulated correction amount $\Sigma\Delta 26F$ ($\Sigma\Delta 26Fc$) saved in the sixteenth temporary memory section M16, and the value in the sixteenth temporary memory section M16 is reset to zero (0), followed by advancing to the next step S322.

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At step S322, it is decided to determine whether the accumulated correction amount $\Sigma\Delta 26R$ ($\Sigma\Delta 26Rc$) saved in the seventeenth temporary memory section M17 exceeds a predetermined acceptable value. When it is decided that the accumulated correction amount does not exceed the predetermined acceptable value, then the program goes to step S324. On the other hand, when it is decided that the accumulated correction amount exceeds the predetermined acceptable value, then the program goes to step S323. The acceptable value so referred to herein likewise corresponds to an acceptable scope of a deviation from a uniform distribution of illuminance on the wafer W, and the acceptable value can be optionally set by the operator operating the projection exposure apparatus according to the present invention.

Then, at step S323, an instruction is given to the condenser lens system drive unit 227 to transfer the rear group 226R of the condenser lens system 226 by the accumulated correction amount $\Sigma\Delta 26R$ ($\Sigma\Delta 26Rc$) saved in the seventeenth temporary memory section M17, and the value in the seventeenth temporary memory section M17 is reset to zero (0), followed by advancing to the next step S324.

Then, at step S324, it is decided to determine whether the accumulated correction amount $\Sigma\Delta 32$ ($\Sigma\Delta 32c$) saved in the eighteenth temporary memory section M18 exceeds a predetermined acceptable value. When it is decided that the accumulated correction amount does not exceed the predetermined acceptable value, then the program goes to

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step S326. On the other hand, when it is decided that the accumulated correction amount exceeds the predetermined acceptable value, then the program goes to step S325. The acceptable value so referred to herein likewise corresponds

5   to an acceptable scope of a deviation from a uniform distribution of illuminance on the wafer W, and the acceptable value can be optionally set by the operator operating the projection exposure apparatus according to the present invention.

10   Then, at step S325, an instruction is given to the drive unit 233 to vary the thickness of the parallel flat panel in the higher-order illuminance irregularity adjustment unit 232 by the accumulated correction amount $\Sigma\Delta32$ ($\Sigma\Delta32c$) saved in the eighteenth temporary memory

15   section M18, and then the value in the eighteenth temporary memory section M18 is reset to zero (0), followed by advancing to the next step S326.

Then, at step S326, it is decided to determine whether the value of the count number N exceeds a predetermined

20   value K. The predetermined value K is a value corresponding to a time axis each of the irradiation duration time table and the irradiation suspension time table. When it is decided that the count number N does not exceed the predetermined value K, then the program goes to step S302.

25   On the other hand, when it is decided that the count number N exceeds the predetermined value K, then the program is terminated.

By executing a sequence of the adjustment of the

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irregularity of illuminance in the manner as described above, the distribution of illuminance on the wafer surface can be maintained always in a uniform fashion or in the form of a predetermined illuminance distribution, even if the

5   transmittance would fluctuate with an elapse of time, thereby improving uniformity of line widths in the shot regions on the wafer and assisting in manufacturing devices of a high quality.

In the examples as described above, the conditions are
10   configured such that each of the correction amount Δ26F, the correction amount Δ26R and the correction amount Δ32 as well as the coefficient δ is saved always at the identical time intervals in the history table, but the time interval (i.e., the interval at which the count number N is counted) is not
15   necessarily set to be identical. Fig. 24 shows a periodical variation of illuminance by irradiation at one point present on the exposure region EA, in which the Y-axis represents illuminance and the X-axis represents an irradiation time. As is apparent from Fig. 24, the illuminance per unit time
20   varies to a steep extent for a while from the point of time immediately after irradiation of light and the variation in illuminance per unit time becomes milder thereafter. Therefore, at step S302, it is not required that count 1 be added to the count number N at every pulse signal from the
25   timer section and that count 1 can be added to the count number N when the pulse signals reach a predetermined number from the timer section, when the variation in illuminance (variation in a distribution of illuminance) per unit time

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is small and mild. At this time, it is needless to state

that the time interval for each of each of the correction

amount $\Delta 26F$, the correction amount $\Delta 26R$ and the correction

amount $\Delta 32$ as well as the coefficient δ to be saved in the

5   irradiation duration time table and the irradiation

suspension time table should be altered in accordance with

the variation in the distribution of illuminance per unit

time. With this configuration, the volume of the

irradiation duration time table and the irradiation

10 suspension time table can be reduced.

Further, in the examples as described above, the

configuration is such that each of the correction amount

$\Delta 26F$, the correction amount $\Delta 26R$ and the correction amount

$\Delta 32$ as well as the coefficient δ per unit time is saved by

15 means of the history tables, however, it can be saved

instead by means of a predetermined function. In this

instance, as a function, there may be used a function $f(t)$

representing a variation in illuminance with respect to the

irradiation time at plural points in the exposure region EA

20 and a function $g(t)$ representing a variation in illuminance

with respect to the irradiation suspension time at plural

points in the exposure region EA. These functions $f(t)$ and

$g(t)$ can be obtained from a result by experiments by means

of techniques such as, for example, the least square method.

25   In this instance, the distribution of illuminance on

the exposure region EA is obtained by computing the

illuminance at each of the plural points of the exposure

region EA by means of the above functions $f(t)$ and $g(t)$, and

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the irregularity of illuminance may be corrected by using

the front group 226F and the rear group 226R of the

condenser lens system 226 as well as the higher-order

illuminance irregularity adjustment unit 232 by means of the

5   techniques as shown in Figs. 18(a) to 18(f), inclusive. At

this time, the memory 210 may be saved with the transferring

amount of the front group 226F and the rear group 226R of

the condenser lens system 226 as well as the adjusting

amount of the higher-order illuminance irregularity

10   adjustment unit 232 in the form corresponding to the

distribution of illuminance on the exposure region EA.

It is to be noted herein that the variation in the

distribution of illuminance can be corrected in accordance

with the history of irradiation by using the predetermined

15   function in the manner as described above.

Moreover, in the examples as described above, the

values of the irradiation duration time table are modified

by the magnitude of the irradiating energy. In accordance

with the present invention, instead, it is also possible,

20   however, to save each of the correction amount $\Delta 26F$, the

correction amount $\Delta 26R$ and the correction amount $\Delta 32$ as well

as the coefficient δ in the table in accordance with the

product obtained by multiplying the irradiation time by the

irradiating energy.

25   In addition, irradiation time tables under a

predetermined irradiating energy and a predetermined

reflectance of a wafer may be prepared each for a

combination of the predetermined irradiating energy with the

reflectance of the wafer, in place of the configuration in which the irradiation duration time table can be modified on the basis of the magnitude of the irradiating energy or the magnitude of the reflectance of the wafer.

5   The projection exposure apparatus in the fourth embodiment of the present invention is directed to a projection exposure apparatus of a scanning type, which is so adapted as to effect the exposure while the projection optical system PL is being transferred relative to the

10   reticle R and the wafer W. In this instance, there may be the occasion that the state of a diffraction light passing through the projection optical system PL may vary with scanning due to a distribution of density of patterns on the reticle R. It is thus preferred that the history tables as

15   described above or the functions f(t) and g(t) are determined by taking into account a variation in the distribution of illuminance due to a variation in the diffraction light.

      In the above examples, the kinds of the reticles R and

20   the illumination conditions are determined primarily. When plural illumination conditions can be set for the reticle R, however, a plurality of irradiation duration time tables are prepared for each of the plural illumination conditions or correction values and coefficients of the irradiation

25   duration time table may be modified in accordance with the illumination conditions, i.e., a modification table is prepared in accordance with the illumination conditions.

      In the method for correcting the variation in the

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distribution of illuminance in accordance with the fourth

embodiment of the present invention, it is preferred that an

actual distribution of illuminance is measured at a

predetermined time interval and that a correction amount

5   from the history table or a correction amount to be computed

by the functions f(t) and g(t) is modified in accordance

with the actual distribution of illuminance measured.

The procedures for this correction method will be

described briefly. First, the main control unit 200 sends

10   an instruction to the wafer stage control unit 261 to

transfer the Y-stage 254 so as to superimpose the light

receipt section 254B of Fig. 15 over the exposure region EA

by the projection optical system PL. At the same time, the

main control unit 200 sends the reticle stage control unit

15   249 to transfer the reticle stage 240 so as to superimpose

the opening portion 240A on the reticle stage 240 over the

exposure region IA. Thereafter, the main control unit 200

sends an instruction to the exposure light amount control

unit 211 to allow the excimer laser light source 212 to emit

20   the exposure light. At this instance, the output from the

photoelectrical conversion element 254E2 in the detection

section 254E as shown in Fig. 15 is associated with the

actual distribution of illuminance. The main control unit

200 compares the actual distribution of illuminance by the

25   output from the photoelectrical conversion element 254E2

with the distribution of illuminance estimated by the

history table or the function, and determines an amount of a

deviation of the estimated distribution of illuminance from

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the actual distribution of illuminance, thereby correcting

the estimated distribution of illuminance on the basis of

the amount of deviation. In this instance, in the examples

as described above, the process is carried out by using the

5   correction amount of the front group 226F and the rear group

226R of the condenser lens system 226 as well as the higher-

order illuminance irregularity adjustment unit 232, not by

using the distribution of illuminance, so that the

comparison can be made after converting the actually

10   measured distribution of illuminance into the corresponding

correction amount.

The timing for measuring the actual distribution of

illuminance in the manner as described above may include,

for instance, loading the reticle at step S201 in the flow

15   chart of Fig. 17, immediately before or after aligning the

reticle or effecting the baseline measurement at step S204,

loading the wafer at step S205, and unloading the wafer at

step S212. The measurement of the distribution of

illuminance immediately before the alignment of the reticle

20   and the baseline measurement is preferable than the

measurement thereof immediately thereafter because no error

is caused to occur upon transferring the opening portion

240A of the reticle stage 240 so as to agree with the

exposure region IA. On the other hand, in the case where

25   the distribution of illuminance is measured at the time of

loading the wafer or unloading the wafer, it is preferred

that the position of the light receipt section 254B is set

so as to be superimposed over the exposure region of the

projection optical system PL upon transferring the Y-stage
254 to the position at which the wafer is loaded.

Further, it is preferred that the time interval for
measuring the actual distribution of illuminance is set to
be shorter at the time of the start of operation after the
operation of the projection exposure apparatus has been
suspended during a long period of time, or immediately after
the shift of the illumination condition.

In the fourth embodiment of the present invention, as
shown in Fig. 15, the illuminance is measured at the plural
locations in the exposure region EA concurrently. For
instance, as shown in Fig. 25(a), the distribution of
illuminance can be measured using the light receipt section
254B having one opening 254B1 by repeating the measurement
while transferring the light receipt section 254B in the X-Y
direction. In this instance, the light receipt section 254B
may preferably be disposed at the position where an image of
the light delivery section 254c is not formed on the
photoelectrical conversion element 254E2, but where the
light from the light delivery section 254C is nearly
collimated, for example, as shown in Fig. 25(b). This
configuration presents the advantage in that an influence of
the photoelectrical conversion element 254B upon the
irregularity of sensitivity can be disregard nearly
completely, because the identical position of the
photoelectrical conversion element 254E2 can be used.

Further, in Fig. 15, the distribution of illuminance
only in the direction perpendicular to the scanning

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direction is measured by taking the effect of canceling the
irregularity of illuminance in the scanning direction upon
scanning exposure into account. However, when it can be
decided that the influence upon the irregularity of

5   illuminance in the scanning direction becomes large, the
distribution of illuminance may be measured in the scanning
direction, too, by using the opening portions 254B1 to
254B21, inclusive, disposed in a matrix form, for example,
as shown in Fig. 25(c).

10   Moreover, as shown in Fig. 15 or Fig. 25, in the case
where the illuminance is measured at the plural locations
concurrently by using the plural pinholes (opening portions)
254B1 to 254B5 and 254B6 to 254B21, the distribution of
illuminance is obtained by repeating the measurement using a

15   particular one (for example, the pinhole 254B1) out of the
plural opening portions by transferring the light receipt
section 254B in the X-Y direction, and by comparing the
distribution of illuminance with the distribution of
illuminance obtained by concurrent measurements at the

20   plural locations, thereby enabling correction of the
influence of the photoelectrical conversion element itself
upon the irregularity of sensitivity.

       Although a description is omitted above, it is
needless to say that the output from the reflectance sensor

25   236 can be used for adjusting the projection magnification β
of the projection optical system PL in a type as disclosed,
for example, in Japanese Patent Application Laid-Open No.
62-183,522 (U. S. Patent No. 4,780,747).

Furthermore, the actual distribution of illuminance only can be measured without using the history table or function, and the irregularity of illuminance on the exposure region can be adjusted on the basis of the result of measurement. In this instance, the distribution of illuminance may be measured immediately before or after the alignment and the baseline measurement at step S204 in the flow chart of Fig. 17, at the time of loading the wafer at step S205, or at the time of unloading the wafer at step S212.

In addition, in the case where the actual distribution of illuminance is measured without using the opening portion 240A in the manner as described above, while the reticle R is stayed loaded, information relating to an ideal distribution of illuminance by the light through the reticle R can be saved in the memory 210, and the ideal distribution of illuminance can be compared with the distribution of illuminance measured through the reticle R.

Next, a description will be made of the example in which the present invention is applied to a projection exposure apparatus of a step-and-repeat type.

Fig. 26 schematically shows the projection exposure apparatus of the step-and-repeat type in the fifth embodiment. The identical members having the same functions as in the embodiment as shown in Fig. 10 are provided with the identical reference numerals and symbols.

The configuration of the projection exposure apparatus of Fig. 26 differs from that of the projection exposure

apparatus of Fig. 10 to a great extent in that the reticle

blind unit 237 is disposed, in place of the reticle blind

unit 228, an illuminance distribution correction unit 238 is

disposed on the leaving plane side of the second fly-eye

5   lens 221, in place of the higher-order illuminance

irregularity adjustment unit 232, and the planar position

detection unit 275 is disposed, in place of the

configuration of the reticle stage, the configuration of the

light receipt portion on the Y-stage 254, and the planar

10   position detection unit 274.

     First, the configuration of the reticle stage will be

described with reference to Fig. 27. In Fig. 27, the

reticle R is adsorbed and fixed on a reticle stage 280, and

the reticle stage 280 is mounted on a reticle support table

15   281 through a bearing, although not shown, so as to move in

all the directions (in the X-direction, the Y-direction and

the direction of rotation (θ)) on the X-Y plane. In Fig. 27,

reference symbols 282A and 283A stand each for a moving

mirror, reference numerals 286 and 287 each for a Y-axial

20   laser interferometer, reference symbols 282B and 283B each

for a fixed mirror, reference symbol 284A for a moving

mirror, reference numeral 288 for an X-axial laser, and

reference symbol 285B for a fixed mirror.

     The X-directional and Y-directional positions are

25   measured always at a resolution of about 0.001 μm, and the

measured value is supplied to the reticle stage control unit

289.

     Further, as shown in Fig. 28, the configuration of the

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X-Y stage is basically the same as in the fourth embodiment,
but it differs therefrom in the configuration of the
reference mark plate 254A and the light receipt section 254B,
each provided on the Y-stage 254. The configuration of the
5   reference mark plate in the projection exposure apparatus of
the step-and-repeat type is disclosed, for example, in
Japanese Patent Application Laid-Open No. 4-324,923 (U. S.
Patent No. 5,243,195) and Japanese Patent Application Laid-
Open No. 6-97,031. In the fifth embodiment of the present
10   invention, the technology disclosed, for example, in
Japanese Patent Application Laid-Open No. 4-324,923 (U. S.
Patent No. 5,243,196), Japanese Patent Application Laid-Open
No. 6-97,031 may be utilized as it is or as modified to some
extent, so that the description of the technology will be
15   omitted hereinafter.

An example of the configuration of the light receipt
section 254B on the Y-stage 254 is shown in Fig. 29. The
fifth embodiment differs from the fourth embodiment in that
the exposure region EA is in a nearly square form and that
20   points for measuring illuminance are disposed over the
nearly entire area of the exposure region EA in order that
the exposure is performed collectively. Fig. 29(a) shows an
example in which plural opening portions 254B1 are disposed
in a matrix form, and Fig. 29(b) shows an example in which
25   plural opening portions 254B1 are disposed in a concentric
form. Like in the fourth embodiment, these plural opening
portions 254B1 are connected each to an optical fiber to
lead the light of the plural opening portions 254B1 to the

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light delivery section 254C.

Then, a description will be made of the illuminance distribution correction unit 238. The illuminance distribution correction unit 238 comprises a plurality of illuminance distribution adjustment members to be disposed selectively in the light path on the incident side of the second fly-eye lens. One of the illuminance distribution adjustment members is shown, for example, in Figs. 30(a) and 3(b) as an illuminance distribution adjustment member 238A. Fig. 30(a) is a plan view showing the fly-eye lens 221 when looked from the side of the illuminance distribution adjustment member 238A, and Fig. 30(b) is a side view thereof. In the configuration as described above, the illuminance distribution adjustment member 238A comprises light amount attenuation sections 238A1 to 238A5, inclusive, each having a predetermined distribution of illuminance to vary the distribution of intensity of the light flux incident to each of lens elements 221A to 221U, inclusive, constituting the second fly-eye lens 221, disposed each on the parallel flat panels. The illuminance distribution adjustment member 238A is disclosed, for example, in Japanese Patent Application Laid-Open No. 7-130,600.

In the fifth embodiment of the present invention, plural illuminance distribution adjustment members, each having a transmittance characteristic different from the illuminance distribution adjustment member 238A, are disposed, in addition to the illuminance distribution adjustment member 238A. Further, these plural illuminance

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distribution adjustment members are disposed on the

illuminance distribution correction unit 238, for example,

in the form of a turret. The drive unit 239 drives the

illuminance distribution correction unit 238 so as to

5   selectively locate one of the illuminance distribution

adjustment members in the illuminance distribution

correction unit 238 in response to an instruction from the

main control unit 200. This operation permits a selective

alteration of the distribution of illuminance on the reticle

10   R or the wafer W. It is to be noted herein that, in the

fifth embodiment of the present invention as described above,

too, the distribution of illuminance of the concave-convex

component and the inclining component are adjusted by

transferring the front group 226F and the rear group 226R of

15   the condenser lens system 226, so that the plural

illuminance distribution adjustment members correct an

irregularity of illuminance that cannot be corrected to a

full extent by the condenser lens system 226.

Moreover, in the fourth embodiment of the present

20   invention, the correction amount of the higher-order

illuminance irregularity adjustment unit 232 is saved in the

history table in the memory 210. In the fifth embodiment,

however, information relating to the kind of the illuminance

distribution adjustment members to be inserted into the

25   light path may be saved, in place of the correction amount

of the higher-order illuminance irregularity adjustment unit

232. In this instance, as the operation for modifying the

correction amount by multiplication by the coefficient as in

the fourth embodiment cannot be adopted in this embodiment, unlike the fourth embodiment, it is preferred that the irradiation duration time tables relating to the illuminance distribution adjustment member under the predetermined

5 irradiation energy and the predetermined reflectance of the wafer are prepared each for a combination of the predetermined irradiation energy with the predetermined reflectance of the wafer.

Then, a brief description will be made of the

10 correction operation. First, the main control unit 200 corrects the distribution of illuminance of the concave-convex component and the inclining component in substantially the same manner as in the fourth embodiment. Further, the main control unit 200 reads information

15 relating to the kind of the illuminance distribution adjustment member from the history table saved in the memory 210 in accordance with the kind of the reticle R, the illumination condition, the output from the integrator sensor 225, and the output from the reflectance sensor 236,

20 and sends the resulting information to the drive unit 238. Then, the drive unit 238 inserts the corresponding illuminance distribution adjustment member into the light path in response to the information from the main control unit 200. This operation can make uniform the distribution

25 of illuminance on the exposure region EA of the wafer W.

The entire exposure sequence in this embodiment is substantially the same as in the fourth embodiment as shown in Fig. 17. The procedures from step S204 to step S208 are

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conducted in accordance with the procedures as disclosed in Japanese Patent Application Laid-Open No. 4-324,923 and Japanese Patent Application Laid-Open No. 6-97,031. The scanning exposure at step S210 differs from the fourth

5   embodiment in that the exposure is effected in a collective manner.

Concerning the controls of the exposure light amount, the technology as disclosed in Japanese Patent Application Laid-Open No. 8-250,402 is used as modified in the fourth

10   embodiment. In the second embodiment, the technique is used where the target exposure light amount is multiplied by the variation portion of transmittance as the coefficient in the method for controlling the exposure light amount as disclosed in Japanese Patent Application Laid-Open No. 2-

15   135,723 (U. S. Patent No. 5,191,374). The technique for multiplying the variation portion of the transmittance as a coefficient in this embodiment is substantially the same as that adopted in the fourth embodiment, only with the exception that the actual coefficient is different.

20   Therefore, an explanation will be omitted hereinafter.

Turning back to Fig. 26, the fifth embodiment of the present invention is different from the fourth embodiment in the configuration of the reticle blind. In the fifth embodiment, the reticle blind 237 is identical to the fourth

25   embodiment in that it is disposed at the position conjugated with the pattern-forming plane of the reticle R between the condenser lens system 226 and the relay optical system 230. The reticle blind 237 in the fifth embodiment, however, is

different from that in the fourth embodiment in that the former has four movable edges to define the illumination region, in place of the movable blind 228A and the fixed blind 228B in the fourth embodiment. The configuration of the reticle blind is disclosed, for example, in Japanese Patent Application Laid-Open No. 2-116,115.

Further, as the planar position detection unit 274 in the fourth embodiment of the present invention, there is used the one disclosed in Japanese Patent Application Laid-Open No. 6-260,391 or 6-283,403. In the fifth embodiment of the present invention, as the planar position detection unit 275, there is used the one as disclosed, for example, in Japanese Patent Application Laid-Open No. 5-275,313 (U. S. Patent No. 5,502,311) or Japanese Patent Application Laid-Open No. 7-142,324 (U. S. Patent No. 5,602,359).

Moreover, in the fourth embodiment of the present invention, the opening portion of the reticle stage 240 is superimposed over the illumination region IA upon measuring the actual distribution of illuminance at the predetermined time interval and modifying the correction amount to be computed by the history table or the functions f(t) and g(t). In the fifth embodiment, on the other hand, the technique can be used such that the actual distribution of illuminance is measured in such a state that the reticle R is detached from the reticle stage 280 or the actual distribution of illuminance is measured in such a state that the reticle R is stayed disposed thereon, and the measured value is compared with information saved in the memory 210 relating

to an ideal distribution of illuminance by the light through the reticle R.

In the fifth embodiment of the present invention, too, one opening portion may be disposed on the light receipt section 254B, in place of the plural opening portions 254B1 (the plural points for measurement), and the measurement can be repeated while transferring the light receipt section 254B in the X-Y direction. Furthermore, the results of the simultaneous measurement for the plural opening portions 254B1 can be calibrated on the basis of the result of measurement for the distribution of illuminance by the particular one out of the plural opening portions 254B1.

In addition, each of the elements as used in from the first embodiment to the fifth embodiment, inclusive, can be associated in an electrical, mechanical or optical way to integrate the projection exposure apparatus according to the present invention.